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# Ecology and Distribution of Major Diatom Ecotypes in the Southern Fort Union Coal Region of Montana

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 1289





# Ecology and Distribution of Major Diatom Ecotypes in the Southern Fort Union Coal Region of Montana

By L. L. BAHLS, E. E. WEBER, *and* J. O. JARVIE

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G E O L O G I C A L   S U R V E Y   P R O F E S S I O N A L   P A P E R   1 2 8 9

*Major diatom ecotypes are systematically described in terms of taxonomy and morphology, abundance, ecology, distribution, and water-quality variables*



DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

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**Library of Congress Cataloging in Publication Data**

Bahls, Loren L.

Ecology and distribution of major diatom ecotypes in the southern Fort Union coal region of Montana.

(Geological Survey professional paper ; 1289)

Bibliography: p.

Supt. of Docs. no.: I 19.16:1289

1. Diatoms—Montana—Fort Union coal region—Ecology. 2. Water quality bioassay—Montana—Fort Union coal region.  
3. Plant indicators—Montana—Fort Union coal region. I. Weber, E. E. II. Jarvie, J. O. III. Title. IV. Title:  
Southern Fort Union coal region of Montana. Series.

QK569.D54B24 1983 589.4 '81 Q450978622 83-600056

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### CONVERSION FACTORS FOR METRIC EQUIVALENTS

Inch-pound unit		Metric unit
To convert	Multiply by	To obtain
Cubic foot per second (ft <sup>3</sup> /s)	28.32	Liter per second
Foot (ft)	0.3048	Meter
Micromho per centimeter at 25 ° Celsius ( $\mu$ mho/cm)	1.000	Microsiemens per centimeter at 25 ° Celsius
Mile (mi)	1.609	Kilometer
Square mile (mi <sup>2</sup> )	2.590	Square kilometer
Degrees Fahrenheit (°F)	Subtract 32 and divide by 1.8	Degrees Celsius (°C)

The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

# ECOLOGY AND DISTRIBUTION OF MAJOR DIATOM ECOTYPES IN THE SOUTHERN FORT UNION COAL REGION OF MONTANA

By L. L. BAHLS, E. E. WEBER, and J. O. JARVIE<sup>1</sup>

## ABSTRACT

From 1975 through 1980, samples were collected to determine the ecology and distribution of the major diatom ecotypes in the southern Fort Union coal region of Montana. Altogether, 370 diatom samples and 289 concurrent water-quality samples were collected at 52 surface-water stations. Sixty-eight major diatom ecotypes were selected for identification on the basis that their percent relative abundance equaled or exceeded 10 following proportional counts of 300 to 400 frustules.

Each major diatom ecotype is systematically described in terms of taxonomy and morphology, abundance, ecology, and distribution in the study area. Included are tables of 24 water-quality variables of biological significance for each ecotype. Illustrations and brief descriptions of representative specimens are included to document and facilitate identification. This information may be used to help establish water-quality criteria for the region's aquatic communities, to identify indigenous diatoms or diatom groups that are useful as water-quality indicators, and to provide a basis for an ecological classification of the various diatom associations in the study area.

Many of the major diatom ecotypes are identified as having sufficiently narrow ecological amplitudes to be useful as indicators of dissolved solids, suspended sediment, and temperature. These are three of the water-quality variables most likely to be affected by surface mining and related activities.

## INTRODUCTION

The southern Fort Union coal region, the general area in southeastern Montana from the Yellowstone River south to the State line (fig. 1), contains one of this country's largest deposits of shallow coal. Here, the coal has a small sulfur content and can be extracted by surface-mining methods. Recent emphasis on energy independence and a greater reliance on domestic energy resources have accelerated coal mining and related activities that could adversely affect the environment of the region. Of particular concern is water quality and the integrity of biological communities supported by the region's many streams and surface-water impoundments.

Small, simple plants called algae are key components of aquatic ecosystems. Through photosynthesis, algae transform basic raw materials into stored energy which becomes food for aquatic animals. In the relatively small and shallow streams of southeastern Montana, the benthic (bottom) algae or periphyton are most important in terms of primary production and plant diversity; plankton (open water) algae and aquatic macrophytes (more complex plants) are of lesser overall significance

(Bahls, 1980). The importance of benthic algae in streams draining energy resource areas of the Rocky Mountain West is underscored by their inclusion in ecological baseline studies recommended by the U.S. Fish and Wildlife Service (States and others, 1978).

Beyond their inherent value as aquatic producers, algae are useful indicators of water quality. Each species of algae has unique environmental requirements and pollution tolerances. To know the requirements and tolerances of a species is to know something about the water quality of a stream in which the species lives. For cosmopolitan species—those found in suitable habitats around the world—these requirements and tolerances also may reveal something about the water quality of a stream in which the species does not live.

## PURPOSE AND SCOPE

The purpose of this report is to summarize the ecology and distribution of the major diatom ecotypes that live in the southern Fort Union coal region of southeastern Montana. This information may be used to help establish water-quality criteria for the region's aquatic communities, to identify indigenous diatoms or diatom groups that are useful as water-quality indicators, and to provide a basis for an ecological classification of the various diatom associations in the study area. Illustrations and brief descriptions of representative specimens are included to facilitate identification. Only diatoms (Division Bacillariophyta) are treated here for three reasons.

First, diatoms are by far the predominant algae in the southern Fort Union coal region. In the first phase of this study, Bahls (1980) reported the following occurrence percentages in periphyton collections for the major algae classes: Bacillariophyceae (diatoms), 100; Chlorophyceae (green algae), 78; Cyanophyceae (blue-green algae), 52; all other classes (Charophyceae, Euglenophyceae, Xanthophyceae, Chrysophyceae, Dinophyceae, Rhodophyceae), less than 20. These findings are supported by those of Olson-Elliott and Associates (1977) and Whalen (1979).

Second, diatoms and other unicellular algae are grazed by certain aquatic invertebrates in preference

<sup>1</sup>Authors are with the Water Quality Bureau, Montana Department of Health and Environmental Sciences, Helena, Mont. Research supported by the U.S. Geological Survey, Department of the Interior, under contract No. 14-08-0001-G-665.

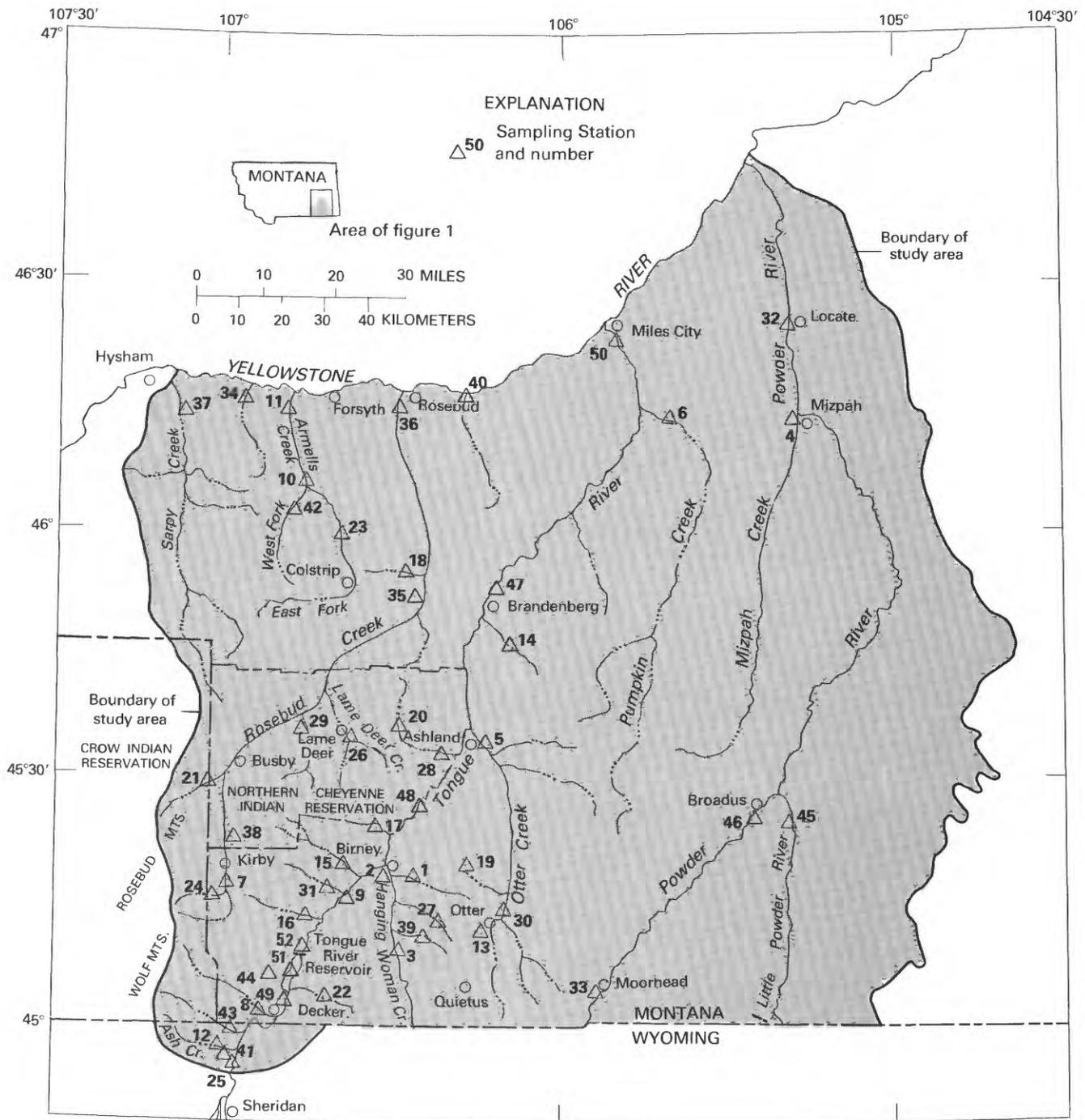


FIGURE 1.—Location of study area and water-quality stations.

to larger and coarser filamentous algae (Merritt and Cummins, 1978). Unlike other algae, diatoms rarely build massive standing crops (blooms) that snag fishing lines, decrease dissolved-oxygen concentrations, or render the water unsightly (Taylor and others, 1981). And unlike certain blue-green algae (Carmichael,

1981), freshwater diatoms have not been reported to be toxic to warm-blooded animals (Jackson, 1964; Palmer, 1977; Werner, 1977).

Third, diatoms are more practical water-quality indicators than soft-bodied algae and other aquatic organisms for the following reasons. Diatoms are single-celled

plants with a rigid, nearly indestructible integument, thereby aiding enumeration, preservation, and storage. They are ubiquitous on stream bottoms, may be captured without expensive equipment, and almost always can be collected in sufficient quantity to meet statistical requirements. A given reach of stream may have dozens of different diatom species, each with a different set of environmental preferences and pollution tolerances. Moreover, a rather extensive amount of literature exists on diatom ecology and taxonomy (Lowe, 1974).

#### ECOTYPES AND INDICATORS

The bewildering array of closely related and generally intergrading varieties and species commonly found in benthic diatom associations is a formidable obstacle to one who would use the diatoms to assess water quality. For routine water-quality monitoring, however, it is sometimes unnecessary to distinguish between similarly appearing, closely related and co-existing taxa because they commonly have very similar ecological preferences and pollution tolerances. Consequently, an ecotype approach rather than a strict taxonomic approach is adopted here to simplify the use of diatoms as water-quality indicators, particularly for those who have neither the time nor the resources for a rigorous taxonomic analysis.

Hanson and Churchill (1961) define ecotype as a cluster of biotypes, within a species, occupying a particular habitat. A biotype, according to this definition, is a population of a species within a given microhabitat belonging to one genotype. For the most part, an ecotype is designated herein by a species, and biotypes by varieties of that species. Each species (ecotype) in this report may contain as many as six varieties (biotypes) that have similar ecological affinities based on repeated co-occurrence in the study area. In several instances, an ecotype is identified as a single variety because it is presumed to be ecologically distinct from another variety that is also found in the study area. In some instances, a form or even another closely related species is designated as a biotype; the ecological counterpart for form is ecoform (phenotype) and for another closely related species is ecospecies.

Two criteria were considered in clustering biotypes. One, they co-exist in the majority of the collections in which they are found; and two, they are morphologically very similar to and generally intergrade with one another. The ecotype is assigned to the species that includes the most common biotype of the study area, except in those instances where a variety is designated as an ecotype. However, a given species may contain additional ecotypes and biotypes in aquatic habitats not sampled during this survey, either inside or outside the southern Fort Union region. The ecological

amplitude of the designated ecotype spans the ecological amplitudes of all the recorded biotypes in the study area.

The real danger in the ecotype approach is that it will forfeit a certain quantity of ecological information. Ecotypes of large ecological amplitude generally are composed of a number of biotypes or ecoforms, each perhaps with a much smaller ecological amplitude. The authors believe, however, that whatever information is lost will be more than compensated for by the ease with which intergrading and often confusing forms may be assigned to a common ecological type.

Certain ecotypes (clusters of biotypes), particularly those containing more than one species, will raise questions concerning appropriate degrees of taxonomic classification. Are varieties and species within the same ecotype indeed distinct genotypes or are they just phenotypic expressions (ecoforms) of this genotype? Posing such questions to serious students of diatom classification may be viewed as a secondary purpose of this report.

The number of diatom taxa in the southern Fort Union coal region is unknown but is estimated to be about 500. A diatom is most valuable as a water-quality indicator if it is present in substantial numbers. Many so-called indicator organisms may be present within a broad range of environmental conditions but will prosper—that is, produce a large number of individuals—only within certain limits. A taxon that contributes only a small percentage of frustules to the total diatom association may be just barely existing or be totally incidental to the aquatic system that was sampled. For example, a taxon might have been introduced from upstream, from the soil of the adjacent streambank or as the result of some random and unpredictable occurrence, such as a visit by a transient shorebird with feet contaminated with algae from a foreign ecosystem. Consequently, diatoms having relatively small populations usually do not make suitable water-quality indicators nor are they particularly important in terms of the total bioenergetics of the aquatic community. Therefore, ecological summaries have been prepared only for those diatom ecotypes from the southern Fort Union region that accounted for 10 percent or more relative abundance (as determined by a proportional count of 300 to 400 frustules) in one or more collections. A total of 68 such ecotypes was evaluated.

#### PREVIOUS WORK

This report is a continuation of data evaluation for the benthic biological inventory of the southern Fort Union coal region initially sponsored by the U.S. Bureau of Land Management and supported by the U.S. Geological Survey under research grant number

14-08-0001-G-503. The inventory data report (Klarich and others, 1980) tabulates chemical, physical, and biological data collected during the inventory, including major diatom taxa in each periphyton collection. Bahls (1980) explored the effect of salinity on the structure (diversity) of benthic algae associations and found little apparent effect among streams in the study area. Klarich and Regele (1980) described the structure, salinity relationships, and other characteristics of benthic macroinvertebrate associations in streams draining the coal-field region. Regele and others (1982) list taxa of higher aquatic plants and genera of macroalgae and microalgae from the study area along with those from the Poplar River basin in northeastern Montana.

All algal analyses from the southern Fort Union coal region performed by or known to Montana Water Quality Bureau personnel were considered in compiling the list of major diatom ecotypes described in this report. In addition to the collections made specifically for the benthic biological inventory are analyses performed for the Bureau's biological monitoring program (unpublished data) and the Bureau's Tongue River project (Bahls and Bahls, 1977), studies by Olson-Elliott and Associates (1977, 1979, 1981) and Whalen (1979), and one incidental collection in a previously unsampled hydrologic unit—the Little Powder River near Broadus (station 45). Those collections with concurrent water-quality data form the basis of the ecological summaries presented herein.

#### PHYSICAL SETTING

The study area is approximately that part of the Fort Union coal region in Montana south of the Yellowstone River (fig. 1). The area extends from the Sarpy Creek drainage on the west to the Powder River drainage on the east. The southern boundary of the study area matches the Montana-Wyoming border except for a small part of Wyoming along the Tongue River drainage to near the mouth of Ash Creek north of Sheridan, Wyo. (station 41).

The entire study area is within the Yellowstone River basin and includes parts of drainages of the Tongue and Powder Rivers, Rosebud Creek, and several small tributaries to the Yellowstone River between Hysham and Miles City, Mont. The study area encompasses all or parts of eight U.S. Geological Survey surface-water hydrologic units (fig. 2), which are used to plot geographic distributions of the major diatom ecotypes within the southern Fort Union coal region.

Descriptions of the area, including geography, hydrology, soils, climate, and water quality have been prepared by Knapton and McKinley (1977) and Knapton and Ferreira (1980). The study area is predomi-

nantly rural and agricultural, with cattle grazing the principal land use.

#### ACKNOWLEDGMENTS

Duane A. Klarich conceived and initiated the original benthic biological inventory of the southern Fort Union coal region, which was sponsored by the Bureau of Land Management and the Geological Survey. Duane A. Klarich and Stephen M. Regele collected most of the samples upon which this report is based. Peggy A. Bahls contributed a substantial amount of her time toward the tedious task of calculating and tabulating diatom percent relative abundance data. Sincere thanks also are extended to the Northern Cheyenne Indian Tribe and to those private landowners who permitted access to sampling stations on their lands; to Dan Corwin for scanning electron-microscope photographs of difficult taxa; and to Charles W. Reimer who assisted the principal author with taxonomic problems on numerous occasions. J. Platt Bradbury, Rex L. Lowe, and Cornelius I. Weber provided helpful and constructive reviews of the manuscript.

#### ENVIRONMENTAL MEASUREMENTS

Altogether, 370 diatom samples and 289 concurrent water-quality samples were collected at 52 sampling stations on 38 bodies of water, including 34 rivers and creeks, 1 reservoir, 1 spring, 1 roadside slough, and 1 discharge from a surface coal mine (table 1 and fig. 1). Each flowing-water station consisted of a stream reach as much as 10 miles long. Occasionally a different site was sampled on successive visits, to a maximum of six discrete points within a given reach (station) during the course of the study. Collections were made from 1975 through 1980 and included all months of the year except December and January. Nine stations on eight significant streams in the study area were selected for intensive seasonal analysis, 34 accessory stations were sampled less intensively, and nine additional stations were added from other biological inventories and monitoring programs conducted by Water Quality Bureau personnel (table 1). Sampling stations (fig. 2) and diatom collections (fig. 3) are distributed among the region's hydrologic units. Note that unit 10100001 is divided into two parts; the eastern part is represented exclusively by six collections from one station on Sweeney Creek (station 40).

#### CHEMICAL AND PHYSICAL MEASUREMENTS

Of the 33 water-quality variables that were measured during the initial inventory (Klarich and others, 1980),

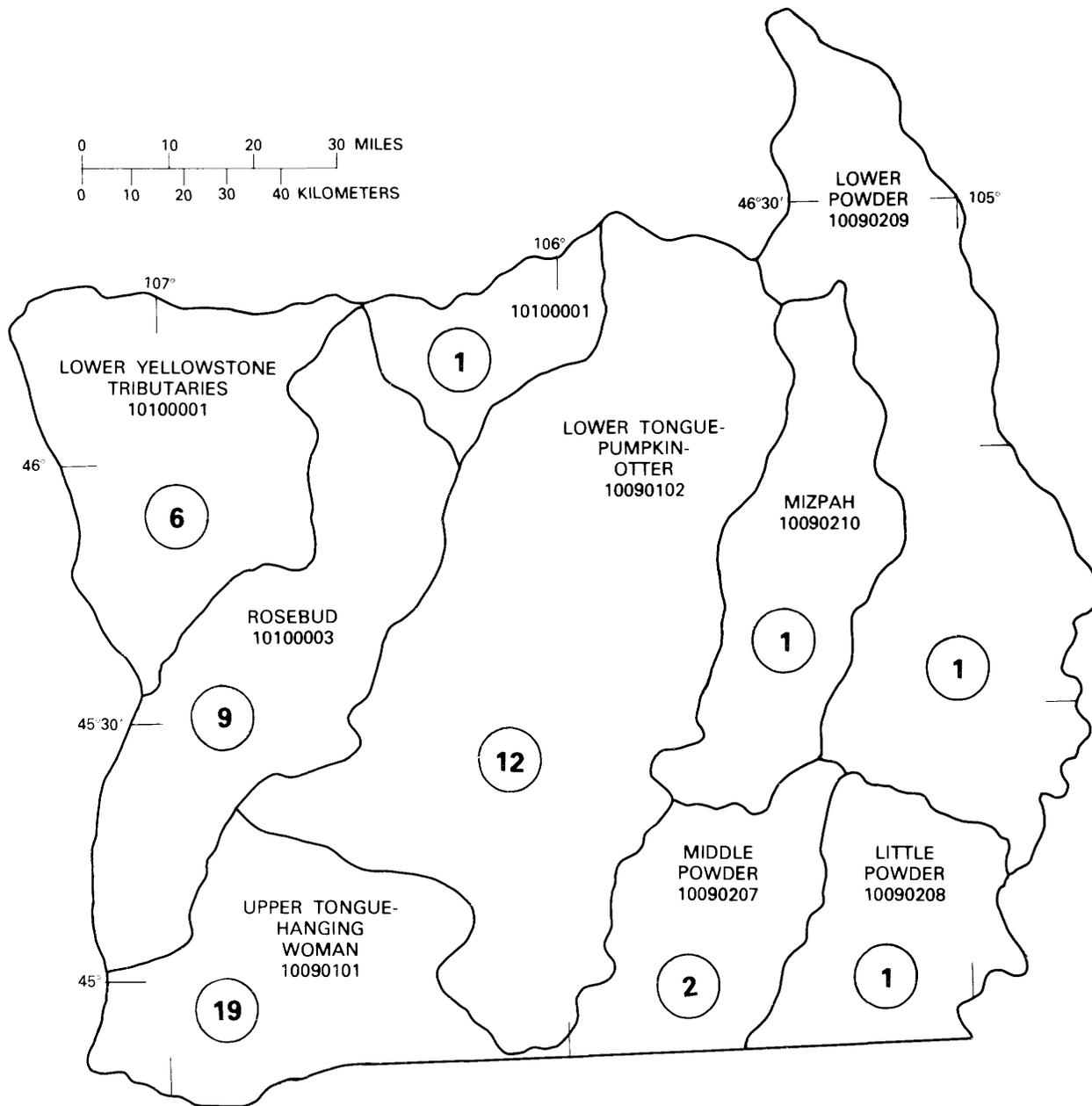


FIGURE 2.—Number of sampling stations (circled) in each of the eight hydrologic units of the study area. Hydrologic unit 10100001, lower Yellowstone tributaries, comprises two areas in the northwest part of the map.

24 variables of biological significance were selected to construct water-quality profiles for the major diatom ecotypes (table 2). One or more of these variables were measured concurrently for 289 of the diatom collections. Silica, a variable of obvious importance to diatoms, was not included because of its consistently nonlimiting concentrations. Measured silica concentrations ranged from 2.8 to 30.0 mg/L (milligrams per liter) and averaged 15.1 mg/L. Silica becomes limiting to diatoms only at concentrations less than about 0.8 mg/L (Hutchinson, 1957).

Grab samples of water were collected in plastic, 1-liter bottles and appropriately preserved or refrigerated for transport and storage according to U.S. Environmental Protection Agency (1979) guidelines. Most variables (common ions, nitrogen, phosphorus, iron, and manganese) were analyzed by the Chemistry Laboratory Bureau of the Montana Department of Health and Environmental Sciences in Helena, Mont. Other variables (specific conductance, pH, temperature, turbidity, dissolved oxygen, biochemical oxygen demand, and suspended sediment) were measured

TABLE 1.—Number of diatom collections from each sampling station

[All stations are in Montana unless otherwise indicated]

Map number (fig. 1)	Sampling station	Number of collections	Map number (fig. 1)	Sampling station	Number of collections
<b>Intensive stations:</b>			<b>Accessory stations—continued:</b>		
1-----	East Fork Hanging Woman Creek near Birney	19	27-----	Lee Creek near Birney	1
2-----	Hanging Woman Creek near Birney	27	28-----	Logging Creek near Ashland	5
3-----	Hanging Woman Creek near Quietus	19	29-----	Muddy Creek near Busby	6
4-----	Mizpah Creek near Mizpah	13	30-----	Otter Creek near Otter	7
5-----	Otter Creek near Ashland	23	31-----	Prairie Dog Creek near Birney	3
6-----	Pumpkin Creek near Miles City	13	32-----	Powder River near Locate	3
7-----	Rosebud Creek near Kirby	19	33-----	Powder River near Moorhead	1
8-----	Squirrel Creek near Decker	31	34-----	Reservation Creek near Forsyth	7
9-----	Tongue River near Pyramid Butte	19	35-----	Rosebud Creek near Colstrip	9
			36-----	Rosebud Creek near Rosebud	4
			37-----	Sarpy Creek near Hysham	6
			38-----	Slough near Kirby	1
			39-----	Stroud Creek near Quietus	3
			40-----	Sweeney Creek near Rosebud	6
			41-----	Tongue River near Sheridan, Wyoming	5
			42-----	West Fork Armells Creek near Colstrip	4
			43-----	Youngs Creek near Sheridan, Wyoming	5
<b>Accessory stations:</b>			<b>Additional stations:</b>		
10-----	Armells Creek near Colstrip	1	44-----	Decker Mine outfall	1
11-----	Armells Creek near Forsyth	5	45-----	Little Powder River near Broadus	1
12-----	Ash Creek near Sheridan, Wyoming	3	46-----	Powder River near Broadus	3
13-----	Bear Creek near Otter	2	47-----	Tongue River near Brandenburg	7
14-----	Beaver Creek near Ashland	7	48-----	Tongue River near Birney	27
15-----	Bull Creek near Birney	2	49-----	Tongue River near Decker	1
16-----	Canyon Creek near Pyramid Butte	4	50-----	Tongue River near Miles City	3
17-----	Cook Creek near Birney	4	51-----	Tongue River Reservoir	5
18-----	Cow Creek near Colstrip	1	52-----	Tongue River Reservoir discharge	1
19-----	Cow Creek near Fort Howe	3			
20-----	Crazy Head Springs (pond) near Ashland	1			
21-----	Davis Creek near Busby	4			
22-----	Deer Creek near Decker	5			
23-----	East Fork Armells Creek near Colstrip	5			
24-----	Indian Creek near Kirby	9			
25-----	Interstate Ditch near Sheridan, Wyoming	1			
26-----	Lame Deer Creek near Lame Deer	5			

TABLE 2.—Statistical summary of physical and chemical data

[ $\mu$ mho/cm, micromhos per centimeter at 25 °C; °C, degrees Celsius; NTU, nephelometric turbidity unit; mg/L, milligrams per liter]

Physical and chemical characteristics	Number of samples	Minimum value	Mean value	Median value	Maximum value
Specific conductance ( $\mu$ mho/cm at 25 °C) -----	281	239	2,251	1,752	11,000
pH (units) -----	280	7.41	8.22	8.22	8.80
Temperature (°C) -----	281	1.0	16.4	17.9	30.5
Turbidity (NTU) -----	274	.5	144.5	8.2	11,600
Oxygen, dissolved (mg/L) -----	205	.80	9.80	9.58	19.04
Biochemical oxygen demand (mg/L) -----	74	.5	2.6	2.2	8.9
Hardness, total (mg/L CaCO <sub>3</sub> ) -----	170	92	804	641	3,485
Calcium, dissolved (mg/L) -----	170	16.0	105.1	86.2	360.0
Magnesium, dissolved (mg/L) -----	170	5.0	131.6	105.0	645.0
Sodium, dissolved (mg/L) -----	182	9.1	309.5	184.5	1,950.0
Bicarbonate (mg/L) -----	191	15.0	480.9	505.0	913.0
Carbonate (mg/L) -----	45	.5	11.3	7.2	38.4
Alkalinity, total (mg/L CaCO <sub>3</sub> ) -----	191	13	400	424	748
Sulfate, dissolved (mg/L) -----	182	17	1,017	582	6,900
Chloride, dissolved (mg/L) -----	182	.4	12.9	6.9	174.0
Fluoride, dissolved (mg/L) -----	177	.0	.7	.6	1.7
Dissolved solids, calculated (mg/L) -----	170	184	2,040	1,489	10,423
Sediment, total suspended (mg/L) -----	252	.2	170.6	13.9	22,550
Nitrogen, total NO <sub>2</sub> + NO <sub>3</sub> (mg/L as N) -----	128	.01	.14	.07	.80
Nitrogen, total ammonia (mg/L as N) -----	159	.01	.04	.02	.57
Phosphorus, total (mg/L as P) -----	191	.010	.088	.039	3.700
Phosphorus, total ortho (mg/L as P) -----	194	.001	.048	.013	2.500
Iron, total recoverable (mg/L) -----	109	.020	.303	.220	2.100
Manganese, total recoverable (mg/L) -----	95	.005	.087	.060	.410

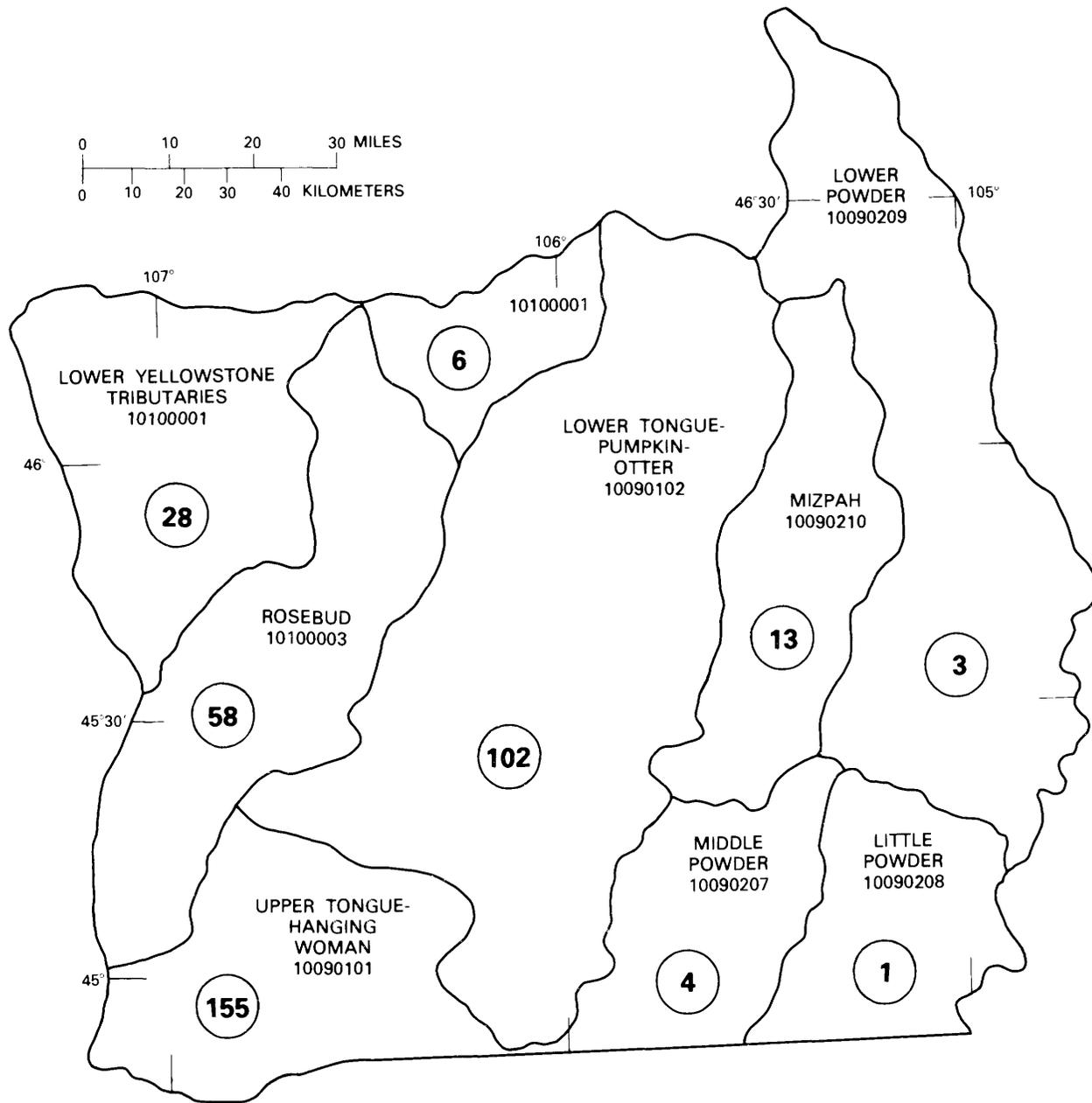


FIGURE 3.—Number of diatom collections (circled) from each of the eight hydrologic units of the study area. Hydrologic unit 10100001, lower Yellowstone tributaries, comprises two areas in the northwest part of the map.

either onsite or in the Water Quality Bureau's branch office laboratory in Billings, Mont. A summary of onsite and laboratory analytical techniques is presented by Klarich and others (1980).

Six additional variables were noted or measured for possible inclusion in each ecotype's ecological summary: date, elevation, instantaneous stream discharge, stream width, substrate reference number, and drainage area upstream from the sampling point (table 3). Elevation and drainage-area values were provided by the U.S. Geological Survey (Paul F. Woods, written

commun., 1980). Discharge, stream width, and substrate reference number were measured as described by Klarich and others (1980). The substrate reference number is the weighted average of the substrate particle sizes at a station; it does not reflect the specific substrate of a given ecotype. Computer-generated histograms were used to compare percent relative abundance values of each ecotype with matching values for each of these six variables. Each histogram was scanned visually, and any apparent correlation or affinity is noted in that ecotype's ecological summary. These histograms are filed at the Water Quality Bureau's office in Helena, Mont.

TABLE 3.—Range of values for six variables considered in the ecological summaries

Variable	Range
Date	February 10–November 7
Elevation (feet above sea level)	2,480–4,100
Stream discharge, instantaneous (cubic feet per second)	0.01–3,300
Stream width (feet)	0.4–48.6
Substrate reference number <sup>1</sup>	1.4–7.4
Drainage area upstream from sampling point (square miles)	2–11,800

<sup>1</sup>Based on a scale of 1 to 8, where 1 is silt- and clay-size particles (less than .05-mm diameter) and 8 is cobble-size particles (greater than 6-cm diameter). Each particle-size number was multiplied by its fractional relative abundance at a site and the products added to obtain the substrate reference number.

#### BIOLOGICAL MEASUREMENTS

Diatom collections from the southern Fort Union coal region were of seven different types based on mode of collection and analytical detail. The types are identified in table 4.

TABLE 4.—Summary of diatom collections

Name	Sample type	Number of samples
Phytoplankton (Tongue River Reservoir)	A	4
Periphyton:		
Grab samples for soft-bodied algae	B	26
Composite samples		340
Total		366
Artificial substrate (Plexiglas) samples:		
Long counts (300–400 frustules)	C	36
Short counts (100–200 frustules)	D	2
Total		38
Natural substrate samples:		
Long counts (300–400 frustules)	E	267
Short counts (100–200 frustules)	F	29
List only (too sparse to count)	G	6
Total		302

#### ONSITE METHODS

Only four of the collections were of phytoplankton associations (type A) and these were all from the Tongue River Reservoir, the largest body of water in the study area. Phytoplankton were enumerated from composite samples collected at 1-meter intervals through the euphotic zone using a 5-liter Van Dorn bottle (Whalen, 1979). Of the remaining 366 periphyton collections, 26 were selective grab samples of conspicuous soft-bodied, non-diatom algae (type B). Only diatoms growing in close association with the target algae were collected, albeit unintentionally. The remaining 340 samples were composite algae collections from natural and artificial (Plexiglas) substrates.

Both diatoms and soft-bodied algae were included in composite collections from natural substrates. Conspicuous soft-bodied algae were collected in proportion to their importance relative one to another and to the diatom association as a whole. These algae generally were plucked by hand. Diatoms and less conspicuous soft-bodied algae were scraped or lifted from their substrates with a sharp-edged tool, such as a pocket knife, single-edged razor blade, or scalpel. Diatoms were collected from each substrate about in proportion to the substrate's importance at a station. Samples were placed in small jars containing ambient water and preserved with Lugol's (IKI) solution (American Public Health Association and others, 1975). The ultimate objective was to obtain a replicate, in miniature, of the total periphyton community.

Composite collections from artificial substrates were made only at the nine intensive stations. Plexiglas plates were exposed for at least 1 month prior to sampling, after which time the accumulated periphyton association was removed to a small jar and preserved with Lugol's solution. Details of periphyton collection techniques are presented by Klarich and others (1980).

#### LABORATORY METHODS

Just prior to processing, each sample container was agitated vigorously to attempt to dislodge diatoms from their algal substrates and to cause randomization of diatom frustules. Conspicuous soft-bodied algae were removed individually from the sample container, examined microscopically, and identified to genus. (A classification method for the algae using a diatom example and the different levels of taxonomic identification used in this study are given in table 5.) The rest of the sample was shaken again and a small subsample was pipetted quickly with a soda straw onto a clean glass microscope slide. This subsample was covered with a coverslip and scanned until most of the less conspicuous soft-bodied algae were located, identified to genus, and recorded.

TABLE 5.—Classification method<sup>1</sup> for the algae, with a diatom example

division	Bacillariophyta
class	Bacillariophyceae
order	Fragilariales
family	Fragilariaceae
subfamily	Fragilarioideae
genus <sup>2</sup>	<i>Synedra</i>
subgenus	<i>Synedra</i>
species <sup>3</sup>	<i>ulna</i>
variety <sup>4</sup>	<i>oxyrhynchus</i>
form	<i>mediocontracta</i>

<sup>1</sup>Patrick and Reimer (1966).

<sup>2</sup>Level to which soft-bodied algae were identified.

<sup>3</sup>Level at which diatoms were tabulated.

<sup>4</sup>Level to which diatoms were identified.

The rest of the sample then was used to prepare a permanent, randomly strewn diatom mount (American Public Health Association and others, 1975) using concentrated sulfuric acid and potassium dichromate as the oxidizing agents and Cargille's "Carmount-165" as the mounting medium. A diatom proportional count was performed on each slide following the technique outlined by Weber (1973), except that in excess of 300 rather than 250 frustules (cells) were tallied. Such counts, generally between 300 and 400 frustules, are called long counts (types C and E). Diatoms were identified to variety and occasionally to form. Except for a few varietal ecotypes with distinct ecological affinities, diatoms were tabulated at the species level (table 5).

In a small percentage of the samples, the number of diatoms was insufficient to conduct a long count within a reasonable length of time. These collections were subjected to short counts of between 100 and 200 frustules (types D and F). In still fewer samples (type G), the diatoms were too sparse to count even 100 frustules; in such instances the diatom taxa merely were listed as they were observed during a 30-minute scan. Similarly, just a list rather than a proportional count was prepared for the diatoms in each grab sample of soft-bodied algae (type B) on the premise that such a selective sample would not be representative of the total diatom association at that site.

#### PERCENT RELATIVE ABUNDANCE

The 68 major diatom ecotypes identified in this report were selected on the basis of exceeding 10 percent relative abundance in one or more collections. Furthermore, in the ecological summaries and water-quality profiles that follow, the assumption is made that a preference for particular environmental conditions is directly proportional to a taxon's abundance relative to other diatom taxa in the same collection. Consequently, percent relative abundance values in excess of 10 are used to delineate the ecotype's preferred range of environmental conditions, and the ecotype's largest percent relative abundance value is correlated with optimum environmental conditions. This approach requires caution for several reasons.

First, a built-in bias exists against forms that are large or those having inherently slow division rates. Single specimens of some large taxa (for example, *Cymatopleura elliptica*) are equivalent in size and perhaps functional ability to many specimens of certain small taxa (for example, *Achnanthes minutissima*), yet the large taxon may never compose 10 percent of an association by number. Two taxa, each under optimum conditions, will produce different numbers of daughter cells because of inherently different division rates.

Second, a larger number of one taxon relative to others in a collection may give a mistaken impression of successful adaptation to ambient conditions, particularly if the total number of individuals in the collection is small. In some instances the conditions may not be optimum for any taxon, yet one invariably will be the most abundant. A count of frustules per unit area would be a more reliable indicator of success. However, this approach is impractical when dealing with composite collections from natural substrates, a sampling technique designed to compensate for the patchiness of diatom populations in stream environments.

Third, maximum division rate and number of frustules may not be synchronized with optimum environmental conditions. Optimum conditions may be present at the very beginning of a taxon's numerical growth curve and be passed when the maximum percent relative abundance value is recorded.

Finally, a diatom's best physiological condition and functional efficiency may not coincide with its maximum percent relative abundance. Conceivably, an accelerated division rate may be in response to adverse or degrading environmental conditions and the resulting cells may have less vigor than those of preceding generations. Nevertheless, percent relative abundance is the only practical way of rating diatom success among qualitative collections from natural and artificial substrates.

#### DISCUSSION

Several conditions need to be met before a diatom ecotype is useful as a water-quality indicator. First, it needs to be abundant when and where conditions are favorable so that its presence cannot be misconstrued as a random occurrence. By definition, all the major diatom ecotypes included in this report meet this criterion.

Second, the geographic distribution needs to be widespread so that it will serve as an indicator when and where conditions are favorable for its growth and division. *Fragilaria* species X, *Navicula peregrina* var. *lanceolata*, and *Nitzschia supralitorea* are so geographically restricted within the southern Fort Union coal region that they are of limited value as water-quality indicators.

Finally, an ecotype needs to have a relatively narrow ecological amplitude in one or more environmental variables of interest. *Achnanthes minutissima*, *Cocconeis placentula*, *Nitzschia frustulum*, and *Nitzschia palea* have very broad ecological amplitudes in the study area. These are the four most common diatom ecotypes in the southern Fort Union coal region. Careful identification and differentiation of the several

closely related and intergrading forms comprising each of these four ecotypes generally will reveal biotypes (ecoforms?) having more discrete and more useful ecological amplitudes. Distinguishing among the *Nitzschia* biotypes may be more practicable when the American species of *Nitzschia* are given the close taxonomic attention that has been given to species of other genera, as in Patrick and Reimer (1966, 1975). Even so, to distinguish among these forms during diatom enumeration may require more time and expertise than many routine monitoring programs can afford.

Salinity is the water-quality variable of principal concern with regard to surface mining in the southern Fort Union coal region (Karp and Botz, 1975). Much of the region's proposed and existing mining is in the drainage of the Tongue River (Montana Department of State Lands and U.S. Office of Surface Mining Reclamation and Enforcement, 1981). Ironically, the Tongue River now has the best water quality (least salinity) of any major stream in the study area (Knapton and Ferreira, 1980). Tongue River water is used primarily for irrigation, a use that is sensitive to salinity. Waters containing concentrations of dissolved solids in excess of 2,100 mg/L are unsuitable for irrigation under most conditions, whereas concentrations of as much as about one-third this amount (700 mg/L) may be injurious under certain crop, soil, and climate conditions (McKee and Wolf, 1963).

Todd (1970) classifies waters containing 0 to 1,000 mg/L dissolved solids as fresh and waters containing 1,000 to 10,000 mg/L dissolved solids as brackish. Concentrations of dissolved solids in waters of the study area range from 184 to 10,423 mg/L. Consequently, most waters of the study area may be classified as either fresh or brackish. For general purposes, freshwater may be considered suitable for irrigation and brackish water unsuitable or marginally suitable for irrigation.

Most of the major diatom ecotypes of the southern Fort Union coal region are euryhalobous; that is, their preferred salinity range spans both fresh and brackish waters. However, a large number are confined largely to one or the other of these salinity classes (table 6). No plankton samples were collected from brackish-water reservoirs in the study area, hence the nature of plankton diatom associations from such waters is unknown.

Not surprisingly, the freshwater ecotypes in table 6 are the principal dominants in the upstream reaches of Rosebud Creek and the Tongue River, including the Tongue River Reservoir. These streams have smaller concentrations of dissolved solids than other major streams in the study area (Knapton and Ferreira, 1980). If salinity in these two streams increases significantly owing to mining or other activities, one would

expect their diatom associations to be replaced by associations dominated first by more euryhalobous ecotypes and then by one or more of the brackish-water ecotypes in table 6. These diatoms would be available for colonization from tributaries and from other streams in the area that have larger concentrations of dissolved solids. In the foreseeable future, however, concentrations of dissolved solids in the Tongue River are not expected to exceed greatly the brackish water criterion of 1,000 mg/L, even under the worst possible conditions (Woods, 1981).

TABLE 6.—Freshwater and brackish-water diatom ecotypes

Freshwater ecotypes <sup>1</sup>	Brackish-water ecotypes <sup>2</sup>
Periphyton:	Periphyton:
<i>Cocconeis pediculus</i>	<i>Amphora coffeiformis</i>
<i>Diatoma vulgare</i>	<i>Cyclotella meneghiniana</i>
<i>Fragilaria capucina</i>	<i>Cymbella pusilla</i>
<i>Gomphonema tenellum</i>	<i>Cymbella species X</i>
<i>Navicula radiosa</i> var. <i>tenella</i>	<i>Diatoma tenue</i>
<i>Navicula tripunctata</i>	<i>Diploneis smithii</i> var. <i>pumila</i>
<i>Synedra ulna</i>	<i>Entomoneis paludosa</i>
	<i>Epithemia adnata</i>
Phytoplankton:	<i>Gomphonema angustatum</i>
<i>Asterionella formosa</i>	<i>Navicula cincta</i>
<i>Fragilaria crotonensis</i>	<i>Navicula cincta</i> var. <i>rostrata</i>
<i>Stephanodiscus niagarae</i>	<i>Navicula goersii</i>
	<i>Navicula gregaria</i>
	<i>Navicula odiosa</i>
	<i>Navicula pavillardii</i>
	<i>Nitzschia closterium</i>
	<i>Nitzschia communis</i>
	<i>Nitzschia microcephala</i>
	<i>Nitzschia obtusa</i>
	<i>Synedra famelica</i>
	<i>Synedra fasciculata</i>
	<i>Thalassiosira pseudonana</i>

<sup>1</sup>Diatoms classified as freshwater ecotypes are most likely to have their best population development (greater than 10 percent relative abundance) in waters containing less than 1,000 mg/L of dissolved solids.

<sup>2</sup>Diatoms classified as brackish-water ecotypes are most likely to have their best population development (greater than 10 percent relative abundance) in waters containing more than 1,000 mg/L of dissolved solids.

Another water-quality variable of concern regarding surface mining is sediment from disturbed lands (Karp and Botz, 1975). Recorded concentrations of suspended sediment in the study area range from less than 1 mg/L in the Tongue River Reservoir to more than 20,000 mg/L in the Powder River (table 2). Concentrations of suspended sediment greater than 25 mg/L may be expected to inhibit the production of freshwater fish and associated aquatic life (Federal Water Pollution Control Administration, 1968).

Most of the major diatom ecotypes from the southern Fort Union coal region can thrive at suspended-sediment concentrations spanning the 25 mg/L criterion. However,

certain ecotypes are restricted to relatively sediment-free water and others dominate diatom associations primarily in waters that carry more than 25 mg/L suspended sediment (table 7). Notable among the findings of this survey is that few if any of the major diatom ecotypes thrive at extremely large concentrations of suspended sediment, such as those frequently recorded in the Powder River.

TABLE 7.—Clear-water and cloudy-water diatom ecotypes

Clear-water ecotypes <sup>1</sup>	Cloudy-water ecotypes <sup>2</sup>
Periphyton:	Periphyton:
<i>Achnanthes lanceolata</i>	<i>Amphipleura pellucida</i>
<i>Cyclotella meneghiniana</i>	<i>Cyclotella pseudostelligera</i>
<i>Cymbella microcephala</i>	<i>Gomphonema angustatum</i>
<i>Cymbella pusilla</i>	<i>Navicula cincta</i>
<i>Cymbella species X</i>	<i>Navicula goersii</i>
<i>Diatoma vulgare</i>	<i>Navicula odiosa</i>
<i>Epithemia sorex</i>	<i>Navicula pavillardii</i>
<i>Fragilaria construens</i>	<i>Nitzschia communis</i>
<i>Melosira varians</i>	<i>Nitzschia valdestrata</i>
<i>Navicula tripunctata</i>	
<i>Pleurosigma delicatulum</i>	
<i>Surirella ovata</i>	
<i>Synedra fasciculata</i>	
<i>Synedra ulna</i>	
Phytoplankton:	
<i>Asterionella formosa</i>	
<i>Fragilaria crotonensis</i>	
<i>Stephanodiscus niagarae</i>	

<sup>1</sup>Diatoms classified as clear-water ecotypes are most likely to have their best population development (greater than 10 percent relative abundance) in waters containing less than 25 mg/L of suspended sediment.

<sup>2</sup>Diatoms classified as cloudy-water ecotypes are most likely to have their best population development (greater than 10 percent relative abundance) in waters containing more than 25 mg/L of suspended sediment.

Substrate particle size, somewhat related to suspended sediment as well as to bedload, gradient, current velocity, and bedrock geology, also may be affected by activities related to mining. The substrate reference numbers derived in the course of the benthic biological inventory reflect average bottom characteristics throughout an entire stream reach. They are not specific to microhabitats of individual diatom ecotypes and hence they are of little value in circumscribing diatom autecology.

Temperature may be of interest in certain streams of the study area. The Tongue River upstream from Prairie Dog Creek (station 31) is the only stream in the study area classified as a (marginal) salmonid fishery by the Montana Department of Health and Environmental Sciences (1980). The East Fork Lame Deer Creek and an upstream reach of Rosebud Creek on the Northern Cheyenne Indian Reservation have self-sustaining wild brook trout populations and are classified as highest-value fishery resources by the U.S. Fish and Wildlife

Service (1980). Unnatural warming of stream water could be caused by dewatering, sedimentation, thermal discharge, and removal of bank cover. Most of the major diatom ecotypes reproduce best between 10 and 20°C. Only one—*Fragilaria construens*—clearly preferred water less than 10°C, although others may dominate at low temperatures during the winter months. This diatom had its greatest population development in Lame Deer Creek near Lame Deer (station 26). Five ecotypes seemed to prefer temperatures in excess of 20°C. These were *Epithemia adnata*, *Navicula pavillardii*, *Nitzschia amphibia*, *Nitzschia valdestrata*, and *Rhopalodia gibba*.

Additional variables of interest with regard to anticipated development in the southern Fort Union coal region might be algal nutrients, heavy metals, and pH. Phosphorus in study area streams is largely associated with the suspended-sediment fraction of the water (Knapton and Ferreira, 1980). Precisely how much of this phosphorus and how much sediment-adsorbed phosphorus on the stream bottom actually is available to benthic algae is not known. Hence, meaningful ecotype classifications based on different nutrient regimes are difficult to construct and will not be attempted here. The fact that *Nitzschia palea*, a eutrophic diatom (Lowe, 1974), occurred in more than 90 percent of the collections from the southern Fort Union coal region is good evidence that algal growth is seldom limited by nutrient availability in streams of the study area, notwithstanding the generally minimal nutrient concentrations measured in the water column. Despite this apparent nutrient enrichment, many streams in the study area and in eastern Montana have relatively slow periphyton production rates, presumably because of turbidity or lack of stable substrates (Bahls and others, 1981).

Most waters in eastern Montana, including those of the study area, are very hard and would be relatively insensitive to heavy-metals pollution. They also give an alkaline reaction and are well buffered, indicating they would be resistant to acid precipitation and acid mine drainage (Bahls and others, 1981).

## SUPPLEMENTARY INFORMATION

### FORMAT

In the final section of this paper, "Major Diatom Ecotypes," each of the ecotypes is treated in a uniform and systematic manner. Coverage includes taxonomy and morphology, abundance, ecology, and distribution within the study area. The description of each ecotype addresses the following elements where applicable.

## TAXONOMY AND MORPHOLOGY

**Ecotype:** A valid Latin name of the ecotype and the authority for that name.

**Biotype(s):** Valid Latin names and authors of biotypes composing the ecotype within the study area, with the most common biotype (the one exceeding 10 percent relative abundance) indicated by an asterisk (\*).

**Reference:** A bibliographic reference to an accepted description of the most common biotype, including the page on which the description begins and the figure number(s), if illustrated.

**Herbarium slide number:** The accession number of the slide curated into the Water Quality Bureau herbarium that contains representative, diamond-ringed, voucher specimens of the most common biotype.

**Illustration:** An inked drawing of a typical specimen of the most common biotype from the designated herbarium slide as observed under a light microscope. All line scales with diatom drawings are 10  $\mu\text{m}$  (micrometers) in length unless otherwise noted.

**Description:** A brief narrative discussion of the ecotype, including the standard dimensions (length, width and striae per 10  $\mu\text{m}$ ) of the illustrated specimen, distinguishing features, similar taxa, and remarks on taxonomy.

## ABUNDANCE

**Mean percent relative abundance:** The total of all percent relative abundance values for all collections in which the ecotype was found, divided by 370.

**Percent occurrence:** The total number of ecotype occurrences divided by 370 times 100.

**Abundance-occurrence index:** Mean percent relative abundance times percentage occurrence. This index has a maximum possible value of 10,000. It is an indicator of commonness and the chances of finding the ecotype in a diatom collection from the study area.

**Preferred percent occurrence:** The total number of ecotype occurrences greater than or equal to 10 percent abundance divided by 370 times 100.

**Maximum percent relative abundance:** The largest percent relative abundance from the study area regardless of concurrent water-quality data, along with the station number (table 1 and fig. 1), date, and type of collection (table 4) producing the record value.

## ECOLOGY

**Water-quality profile:** A table of statistical values for the 24 chemical and physical variables listed in table 2, giving for the ecotype the *sample size* (number of concurrent water-quality measurements), *range* (minimum and maximum values among concurrently measured values of each variable), *preferred range*

(minimum and maximum values among concurrently measured values of each variable for relative abundance readings equal to or greater than 10 percent), *optimum* (the value for each variable associated with the concurrent collection in which the ecotype achieved its largest percent relative abundance), and the corresponding *percent relative abundance*.

Only those chemical and physical data are used that were generated onsite or extracted from a water-quality sample taken at the same time as a corresponding diatom collection. Occasionally, concurrent water-quality data are not available for collections in which an ecotype accounted for 10 percent or more of the frustules, and in such instances the *preferred range* column is blank. If concurrent data are not available for an ecotype's largest percent relative abundance reading (*optimum*), then data for the next largest reading are used. A water-quality profile does not identify an ecotype's growth-limiting variable nor the specific variables and values causing optimum growth; it simply presents the mixture of values associated with an ecotype's occurrence and peak performance as measured by percent relative abundance.

Abbreviations used in the profiles are:  $\mu\text{mho/cm}$ , micromhos per centimeter at 25 °C; °C, degrees Celsius; NTU, nephelometric turbidity unit; and mg/L, milligrams per liter.

**Ecological summary:** A brief narrative summary of the ecotype's environmental preferences and pollution tolerances, covering the 24 chemical and physical variables, season, discharge, stream size (width), elevation, substrate reference number, and drainage area upstream from the sampling station. Categorical descriptions of water freshness and hardness are based on rating tables presented by Todd (1970). Only those affinities determined from this study are considered in the summary. Emphasis is placed on those variables for which the range of values is much more restricted than for the study area as a whole (table 2).

## DISTRIBUTION

**Distribution summary:** A brief narrative summary of the distribution of the ecotype in the study area, including preferred range, notable outliers, and endemic populations.

**Distribution map:** A map outlining the eight hydrologic units in the study area and the percent relative abundance for each unit. An open circle (○) indicates a small percent relative abundance (less than 10) in all collections from a unit, and a closed circle (●) indicates a larger percent relative abundance (equal to or greater than 10) in one or more collections from a unit. A blank hydrologic unit indicates an absence of record for the ecotype in that unit.

## **MAJOR DIATOM ECOTYPES**

ECOTYPE: *ACHNANTHES LANCEOLATA* BREB. EX KUTZ.

Biotype(s):

- \**A. lanceolata* Breb. ex. Kutz. var. *lanceolata*
- A. lanceolata* var. *dubia* Grun.
- A. lanceolata* var. *haynaldii* (Istv.-Schaarsch.) Cl.

Reference:

Patrick and Reimer, 1966 (p. 269; pl. 18,  
figs. 1-10)

Herbarium slide number:

1-1-18

Mean percent relative abundance:

0.7

Percent occurrence:

49.2

Abundance-occurrence index:

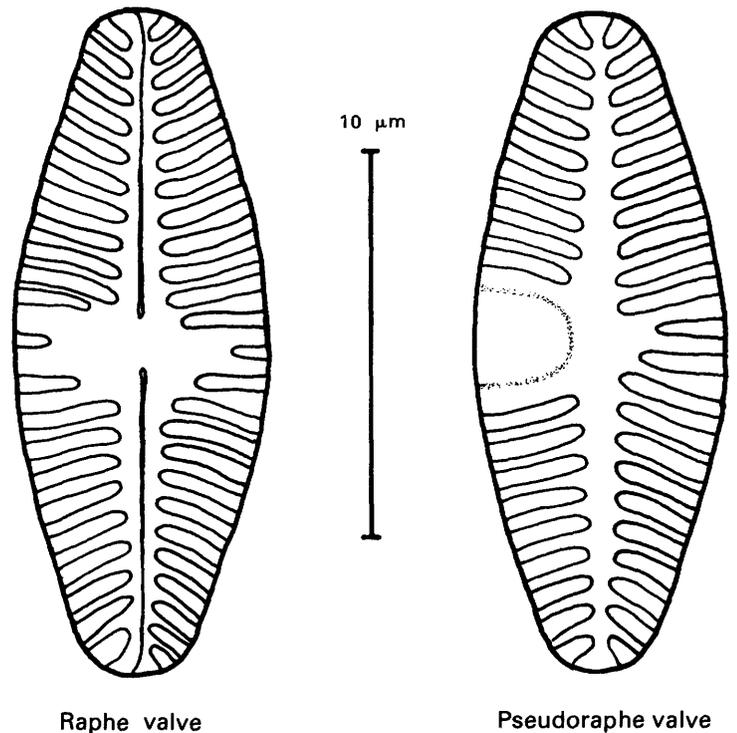
35.9

Preferred percent occurrence:

1.6

Maximum percent relative abundance:

20.7



Station number: 17

Date: August 24, 1978

Type of collection: E

Description:

Striae, 12-14 in 10  $\mu\text{m}$  on both valves. Length, 16.8  $\mu\text{m}$ . Width, 6.5  $\mu\text{m}$ . A robust, largely variable species of *Achnanthes*. Distinguished from *A. hauckiana* Grun. by the central clear area on one side of the pseudoraphe valve.

Water-quality profile:

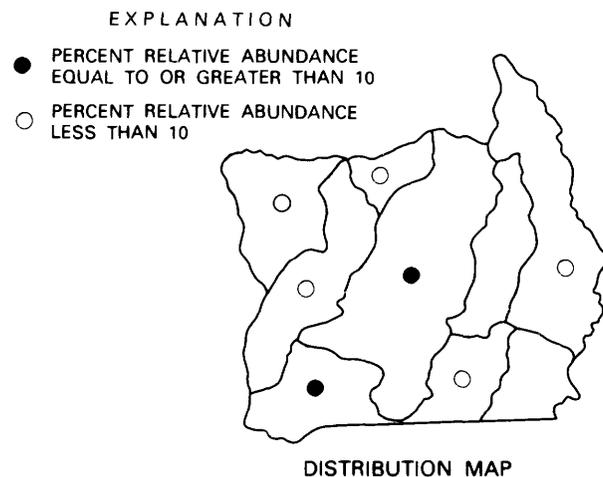
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	153	239-6400	462- 1730	1730(20.7)
pH (units) -----	153	7.50- 8.59	7.85- 8.35	8.35(20.7)
Temperature ( $^{\circ}\text{C}$ ) -----	153	2.0- 27.0	11.5- 19.0	13.5(20.7)
Turbidity (NTU) -----	151	0.5- 435	1.6- 4.4	2.2(20.7)
Oxygen, dissolved (mg/L) -----	110	4.52- 14.3	8.50- 10.3	8.50(20.7)
Biochemical oxygen demand (mg/L) -----	40	0.8- 8.9	2.6- 2.6	2.6(11.7)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	90	124-3320	237- 712	712(20.7)
Calcium, dissolved (mg/L) -----	90	27.4- 330	49.7- 94.0	92.0(20.7)
Magnesium, dissolved (mg/L)-----	90	13.5- 605	26.4- 117	117(20.7)
Sodium, dissolved (mg/L) -----	97	9.1- 665	18.3- 193	193(20.7)
Bicarbonate (mg/L)-----	103	111- 816	250- 671	671(20.7)
Carbonate (mg/L) -----	19	0.5- 24.0	4.1- 5.0	4.1(20.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	103	91- 669	213- 557	557(20.7)
Sulfate, dissolved (mg/L) -----	97	17-4040	41- 579	579(20.7)
Chloride, dissolved (mg/L) -----	97	0.4- 174	0.4- 5.9	0.4(20.7)
Fluoride, dissolved (mg/L) -----	94	0.1- 1.7	1.2- 1.2	1660(20.7)
Dissolved solids, calculated (mg/L) -----	90	196-6290	398-1660	1.9(20.7)
Sediment, total suspended (mg/L) -----	141	0.2- 893	1.5- 19.6	0.39(20.7)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	73	0.01- 0.71	0.03- 0.39	0.01(20.7)
Nitrogen, total ammonia (mg/L as N) -----	86	0.01- 0.57	0.01- 0.11	0.01(20.7)
Phosphorus, total (mg/L as P)-----	107	0.010- 0.60	0.020-0.068	0.068(20.7)
Phosphorus, total ortho (mg/L as P)-----	113	0.001- 0.38	0.001-0.064	0.064(20.7)
Iron, total recoverable (mg/L)-----	71	0.02- 2.1	0.14- 0.29	0.22(20.7)
Manganese, total recoverable (mg/L)-----	63	0.005- 0.41	0.019-0.075	0.064(20.7)

Ecological summary:

Prefers cool waters with little turbidity and small concentrations of chloride and suspended sediment; small streams (less than 1 ft<sup>3</sup>/s) at higher elevations; and substrate the size of coarse sand or larger (greater than 0.3-mm diameter). Summer (June to September) dominant.

Distribution summary:

A widespread ecotype found in all hydrologic units except those representing Mizpah Creek and the Little Powder River. Prefers Tongue River drainage.



ECOTYPE: *ACHNANTHES MINUTISSIMA* KUTZ.

Biotype(s):

- A. linearis* (W. Sm.) Grun. var. *linearis*
- A. linearis* f. *curta* H. L. Sm.
- A. microcephala* (Kutz.) Grun. var. *microcephala*
- \**A. minutissima* Kutz. var. *minutissima*

Reference:

Patrick and Reimer, 1966 (p. 253; pl. 16, figs. 9-10)

Herbarium slide number:

1-1-19

Mean percent relative abundance:

8.3

Percent occurrence:

86.8

Abundance-occurrence index:

721.0

Preferred percent occurrence:

27.3

Maximum percent relative abundance:

69.0

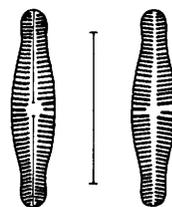
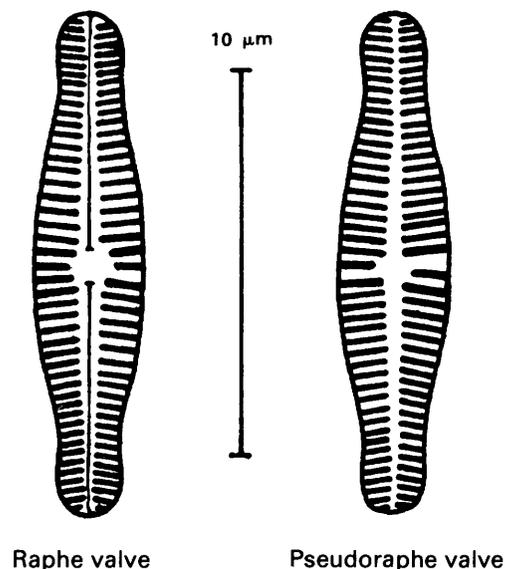
Station number: 16

Date: November 2, 1979

Type of collection: E

Description:

Striae, 30-38 in 10  $\mu\text{m}$  on both valves. Length, 13.0  $\mu\text{m}$ . Width 3.0  $\mu\text{m}$ . A delicate, polymorphic *Achnanthes*. Shape of the ends appears to be a function of frustule size and environmental conditions; obtusely rounded or broadly subrostrate to distinctly capitate, often spanning a continuum of intermediates in one collection. *A. linearis*, *A. microcephala*, and *A. minutissima* may be different expressions of the same genome; their similarities and intergradations make possible genotypic or phenotypic distinctions impractical at the level of resolution achieved by many optical microscopes.



Water-quality profile:

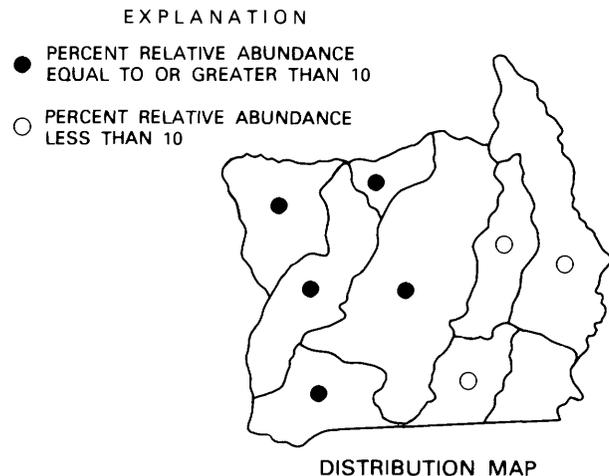
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	264	239-11000	438-6100	1640(69.0)
pH (units)-----	263	7.50- 8.80	7.63- 8.80	8.38(69.0)
Temperature ( $^{\circ}\text{C}$ ) -----	264	1.3- 30.5	2.0- 30.2	4.3(69.0)
Turbidity (NTU) -----	258	0.5- 4200	0.5- 94	0.5(69.0)
Oxygen, dissolved (mg/L) -----	193	4.52- 19.0	5.22- 19.0	13.1(69.0)
Biochemical oxygen demand (mg/L)-----	74	0.5- 8.9	1.0- 8.9	1.9(69.0)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	155	123- 3490	222-2040	500(68.2)
Calcium, dissolved (mg/L) -----	155	16.0- 330	41.8- 254	82.5(68.2)
Magnesium, dissolved (mg/L) -----	155	13.5- 645	25.7- 346	71.0(68.2)
Sodium, dissolved (mg/L)-----	166	9.1- 1950	12.2-1230	148(69.0)
Bicarbonate (mg/L) -----	173	15- 913	171- 755	534(69.0)
Carbonate (mg/L)-----	41	0.5- 38.4	0.5- 38.4	28.0(48.0)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	173	13- 748	146- 619	438(69.0)
Sulfate, dissolved (mg/L) -----	166	17- 6900	17-5450	575(69.0)
Chloride, dissolved (mg/L)-----	166	0.4- 174	1.8- 51.6	5.9(69.0)
Fluoride, dissolved (mg/L)-----	162	0.1- 1.7	0.1- 1.3	0.8(69.0)
Dissolved solids, calculated (mg/L)-----	155	184-10400	389-7680	1150(68.2)
Sediment, total suspended (mg/L)-----	238	0.2- 8260	0.4- 310	0.8(69.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	127	0.01- 0.80	0.01- 0.80	0.80(69.0)
Nitrogen, total ammonia (mg/L as N)-----	151	0.01- 0.57	0.01- 0.22	0.01(69.0)
Phosphorus, total (mg/L as P) -----	180	0.010- 3.7	0.010- 0.25	0.050(68.2)
Phosphorus, total ortho (mg/L as P) -----	183	0.001- 2.5	0.001- 0.15	0.043(68.2)
Iron, total recoverable (mg/L) -----	106	0.02- 2.1	0.02- 2.1	0.07(69.0)
Manganese, total recoverable (mg/L) -----	93	0.005- 0.41	0.005- 0.36	0.025(68.2)

Ecological summary:

This complex has a broad ecological amplitude. Prefers waters with good clarity and little suspended sediment; small to medium streams (0.1 to 10  $\text{ft}^3/\text{s}$ ); and substrate the size of fine gravel (0.2 to 1 cm) or larger. No apparent seasonal preference. The availability of firm, stable attachment sites seems to be the overriding environmental requirement.

Distribution summary:

Widespread, but dominant only in the western part of the study area. The second most common ecotype in the southern Fort Union coal region.



ECOTYPE: *AMPHIPLEURA PELLUCIDA* (KUTZ.) KUTZ.

Biotype(s):

*Amphipleura pellucida* (Kutz.) Kutz. var.  
*pellucida*

Reference:

Patrick and Reimer, 1966 (p. 303; pl. 21,  
figs. 2a-b)

Herbarium slide number:

1-1-20

Mean percent relative abundance:

0.7

Percent occurrence:

41.6

Abundance-occurrence index:

28.9

Preferred percent occurrence:

1.4

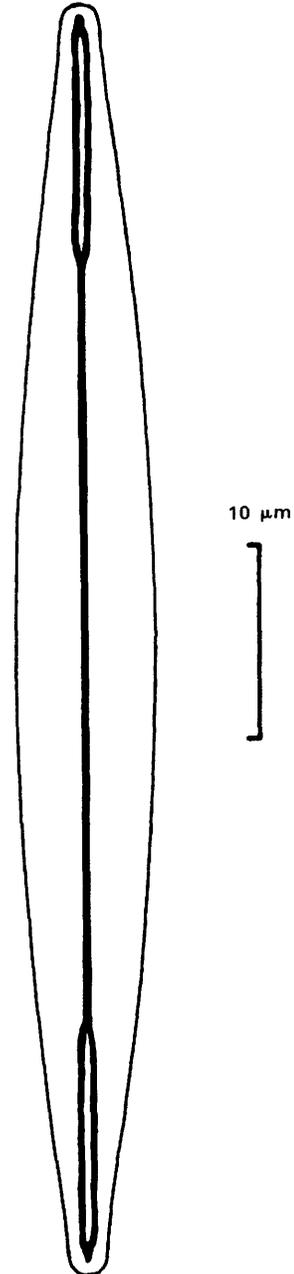
Maximum percent relative abundance:

52.8

Station number: 50

Date: September 28, 1975

Type of collection: E



Description:

Striae, about 40 in 10  $\mu\text{m}$ . Length, 66.0  $\mu\text{m}$ .  
Width, 7.5  $\mu\text{m}$ . A very distinctive but lightly si-  
licified taxon. The only species of *Amphipleura*  
known to date from the study area.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	129	480-11000	938- 2460	956(52.8)
pH (units) -----	129	7.62- 8.73	8.38- 8.60	8.42(52.8)
Temperature ( $^{\circ}\text{C}$ ) -----	127	1.3- 30.5	10.00- 30.5	15.4(52.8)
Turbidity (NTU) -----	126	0.7- 376	1.7- 15	15(38.6)
Oxygen, dissolved (mg/L) -----	92	5.22- 19.0	9.65- 10.9	9.65(52.8)
Biochemical oxygen demand (mg/L) -----	39	0.5- 7.8	0.7- 0.7	0.7(52.8)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	80	123- 3490	123- 370	370(52.8)
Calcium, dissolved (mg/L) -----	80	16.0- 328	16.0- 68.0	68.0(52.8)
Magnesium, dissolved (mg/L)-----	80	20.0- 645	20.0- 48.5	48.5(52.8)
Sodium, dissolved (mg/L) -----	83	11.7- 1950	75.0- 562	75.0(52.8)
Bicarbonate (mg/L)-----	88	171- 913	295- 776	301(52.8)
Carbonate (mg/L) -----	17	0.5- 26.0	5.0- 5.0	5.0(52.8)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	88	146- 748	242- 636	255(52.8)
Sulfate, dissolved (mg/L) -----	83	17- 6900	280- 708	280(52.8)
Chloride, dissolved (mg/L) -----	83	1.2- 174	4.2- 9.8	4.2(52.8)
Fluoride, dissolved (mg/L) -----	81	0.1- 1.7	0.3- 0.6	0.3(52.8)
Dissolved solids, calculated (mg/L) -----	80	389-10400	787- 2100	787(52.8)
Sediment, total suspended (mg/L) -----	119	0.9- 741	5.4- 38.6	38.6(52.8)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	62	0.01- 0.71	0.03- 0.08	0.03(52.8)
Nitrogen, total ammonia (mg/L as N) -----	81	0.01- 0.22	0.03- 0.03	0.03(38.6)
Phosphorus, total (mg/L as P)-----	97	0.010- 0.62	0.020-0.032	0.032(52.8)
Phosphorus, total ortho (mg/L as P)-----	96	0.001- 0.52	0.005-0.005	0.005(52.8)
Iron, total recoverable (mg/L)-----	52	0.05- 1.1	0.34- 0.60	0.60(52.8)
Manganese, total recoverable (mg/L)-----	49	0.010- 0.36	0.050-0.054	0.050(52.8)

Ecological summary:

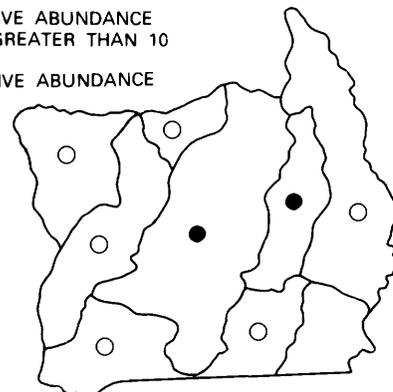
Prefers larger streams (greater than 100 ft<sup>3</sup>/s) at lower elevations (less than 2,500 ft). Tolerant to some turbidity and suspended sediment. Fall (September to November) dominant.

Distribution summary:

Widespread, but dominant only in Mizpah Creek and the downstream part of the Tongue River.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *AMPHORA COFFEIFORMIS* (AG.) KUTZ.

Biotype(s):

*Amphora coffeiformis* (Ag.) Kutz. var. *coffeiformis*

Reference:

Patrick and Reimer, 1975 (p. 78; pl. 14,  
figs. 11-12)

Herbarium slide number:

1-2-1

Mean percent relative abundance:

0.2

Percent occurrence:

10.5

Abundance-occurrence index:

2.0

Preferred percent occurrence:

0.4

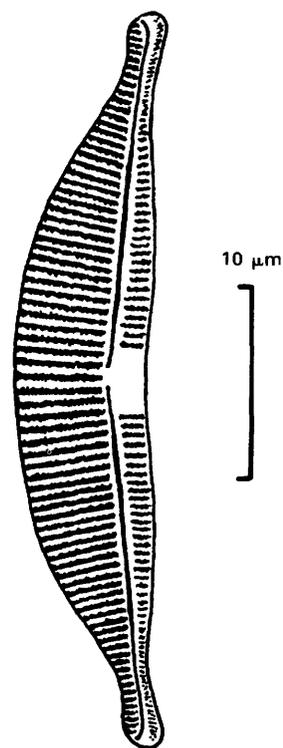
Maximum percent relative abundance:

31.8

Station number: 23

Date: October 28, 1979

Type of collection: E



Description:

Striae, 16-24 dorsal and 22-30 ventral in  
10  $\mu$ m. Length, 38.0  $\mu$ m. Width, 7.5  $\mu$ m. Distin-  
guished from *A. veneta* and *A. perpusilla* by con-  
tinuous rather than dashed or punctate striae.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	37	506–11000	11000–11000	11000(19.1)
pH (units)	37	7.62– 8.70	8.25– 8.25	8.25(19.1)
Temperature ( $^{\circ}\text{C}$ )	37	1.3– 30.5	20.9– 20.9	20.9(19.1)
Turbidity (NTU)	37	0.7– 4200	3.5– 3.5	3.5(19.1)
Oxygen, dissolved (mg/L)	27	6.70– 19.0	15.3– 15.3	15.3(19.1)
Biochemical oxygen demand (mg/L)	8	1.5– 6.0	-----	1.5(1.1)
Hardness, total (mg/L $\text{CaCO}_3$ )	19	123– 3490	3490– 3490	3490(19.1)
Calcium, dissolved (mg/L)	19	16.0– 328	328– 328	328(19.1)
Magnesium, dissolved (mg/L)	19	20.0– 645	645– 645	645(19.1)
Sodium, dissolved (mg/L)	21	19.5– 1950	1950– 1950	1950(19.1)
Bicarbonate (mg/L)	22	244– 913	569– 569	569(19.1)
Carbonate (mg/L)	4	0.5– 22.0	-----	8.4(1.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	22	200– 748	466– 466	466(19.1)
Sulfate, dissolved (mg/L)	21	38– 6900	6900– 6900	6900(19.1)
Chloride, dissolved (mg/L)	21	2.2– 126	30.3– 30.3	30.3(19.1)
Fluoride, dissolved (mg/L)	19	0.04– 1.2	0.4– 0.4	0.4(19.1)
Dissolved solids, calculated (mg/L)	19	425–10400	10400–10400	10400(19.1)
Sediment, total suspended (mg/L)	34	1.3– 3220	6.0– 6.0	6.0(19.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	11	0.02– 0.64	0.02– 0.02	0.02(19.1)
Nitrogen, total ammonia (mg/L as N)	22	0.01– 0.57	0.10– 0.10	0.10(19.1)
Phosphorus, total (mg/L as P)	26	0.010– 2.6	0.62– 0.62	0.62(19.1)
Phosphorus, total ortho (mg/L as P)	24	0.003– 1.8	0.52– 0.52	0.52(19.1)
Iron, total recoverable (mg/L)	11	0.10– 1.1	-----	0.18(1.5)
Manganese, total recoverable (mg/L)	9	0.025– 0.23	-----	0.025(0.3)

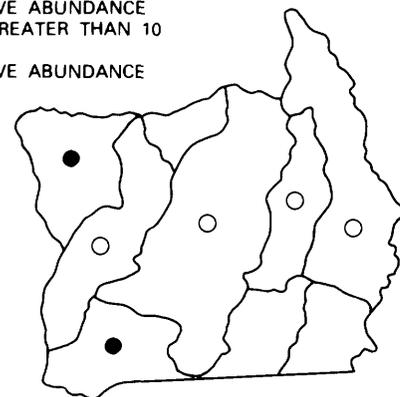
Ecological summary:

Prefers phosphorus-rich, sodium sulfate, brackish to slightly saline waters; and smaller streams (less than 10 ft<sup>3</sup>/s) at middle elevations (2,500 to 3,500 ft). Summer and fall (July to October) dominant.

Distribution summary:

Found only occasionally in collections from the study area. Prefers upstream reaches of Armells Creek and Hanging Woman Creek.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *AMPHORA PERPUSILLA* (GRUN.) GRUN.

Biotype(s):

*Amphora perpusilla* (Grun.) Grun. var. *perpusilla*

Reference:

Patrick and Reimer, 1975 (p. 70; pl. 13,  
figs. 8a-11b)

Herbarium slide number:

1-2-2

Mean percent relative abundance:

1.5

Percent occurrence:

62.2

Abundance-occurrence index:

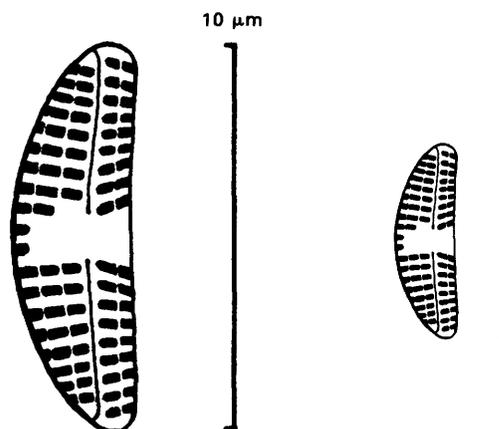
94.1

Preferred percent occurrence:

3.5

Maximum percent relative abundance:

45.4



Station number: 37

Date: November 7, 1979

Type of collection: E

Description:

Striae, 16-20 in 10  $\mu\text{m}$ . Length, 10.2  $\mu\text{m}$ . Width, 3.1  $\mu\text{m}$ . Distinguished from *A. coffeiformis* and *A. veneta* by a shortening of one or two of the central striae on the dorsal side. Distinguished from *A. ovalis* var. *pediculus* (Kutz.) V. H. ex DeT. in that the proximal raphe ends are straight and not sinuous. The smallest species of *Amphora* in the study area.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	189	239–11000	239– 2840	2220(45.4)
pH (units)	189	7.50– 8.72	7.63– 8.40	8.25(45.4)
Temperature ( $^{\circ}\text{C}$ )	188	1.7– 30.5	3.5– 22.8	4.3(45.4)
Turbidity (NTU)	188	0.5– 435	0.9– 53	5.9(45.4)
Oxygen, dissolved (mg/L)	137	4.52– 15.3	7.00– 12.9	12.9(45.4)
Biochemical oxygen demand (mg/L)	50	0.8– 8.9	1.8– 1.8	1.8(18.8)
Hardness, total (mg/L $\text{CaCO}_3$ )	119	123– 3490	363– 1080	453(26.7)
Calcium, dissolved (mg/L)	119	16.0– 328	62.1– 134	70.4(26.7)
Magnesium, dissolved (mg/L)	119	13.5– 645	48.9– 184	67.0(26.7)
Sodium, dissolved (mg/L)	125	9.1– 1950	11.5– 322	322(45.4)
Bicarbonate (mg/L)	131	15– 816	339– 610	573(45.4)
Carbonate (mg/L)	25	0.5– 36.0	6.7– 7.0	6.7(18.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	131	13– 669	278– 500	470(45.4)
Sulfate, dissolved (mg/L)	125	17– 6900	70– 1070	750(45.4)
Chloride, dissolved (mg/L)	125	0.4– 88.9	2.4– 12.2	12.2(45.4)
Fluoride, dissolved (mg/L)	123	0.1– 1.7	0.3– 1.2	0.4(45.4)
Dissolved solids, calculated (mg/L)	119	184–10400	568– 2250	830(26.7)
Sediment, total suspended (mg/L)	174	0.2– 893	0.9– 61.0	9.4(45.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	100	0.01– 0.71	0.02– 0.38	0.19(45.4)
Nitrogen, total ammonia (mg/L as N)	110	0.01– 0.22	0.01– 0.05	0.02(45.4)
Phosphorus, total (mg/L as P)	133	0.010– 0.62	0.017– 0.12	0.020(45.4)
Phosphorus, total ortho (mg/L as P)	136	0.001– 0.52	0.003– 0.058	0.003(45.4)
Iron, total recoverable (mg/L)	81	0.02– 2.1	0.04– 1.1	0.24(45.4)
Manganese, total recoverable (mg/L)	78	0.005– 0.41	0.010– 0.26	0.050(45.4)

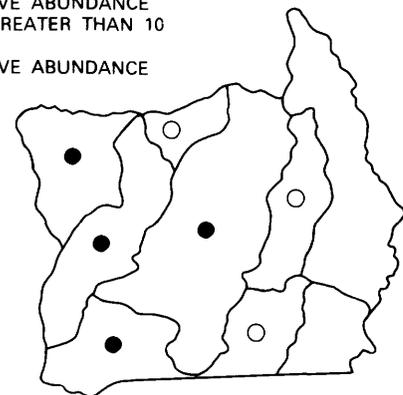
Ecological summary:

Prefers cool waters at middle elevations (2,500 to 4,000 ft); and smaller streams (0.1 to 10  $\text{ft}^3/\text{s}$ ). Tolerates some sediment and turbidity; does best on fine to medium gravels (0.2 to 3 cm diameter). No seasonal preference evident.

Distribution summary:

Widely distributed. Most abundant in the western part of the study area.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *AMPHORA VENETA* KUTZ.

Biotype(s):

*Amphora veneta* Kutz. var. *veneta*

Reference:

Patrick and Reimer, 1975 (pl. 72; pl. 14, figs. 2-3)

Herbarium slide number:

1-2-3

Mean percent relative abundance:

0.3

Percent occurrence:

18.9

Abundance-occurrence index:

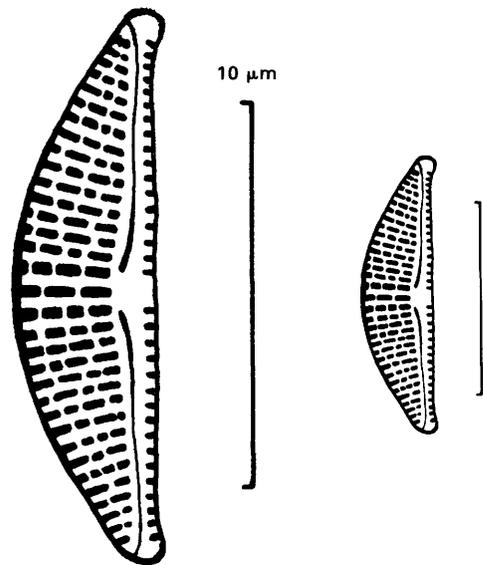
5.1

Preferred percent occurrence:

1.1

Maximum percent relative abundance:

15.8



Station number: 6

Date: July 21, 1978

Type of collection: E

Description:

Striae, 17-27 dorsal and 24-27 ventral in 10  $\mu\text{m}$ . Length, 14.3  $\mu\text{m}$ . Width, 3.8  $\mu\text{m}$ . Distinguished from *A. coffeiformis* by dashed rather than continuous striae and from *A. perpusilla* by the absence of shortened central striae on the dorsal side.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	61	333- 6000	598-1880	920(15.8)
pH (units) -----	61	7.41- 8.73	7.41- 8.41	7.65(15.8)
Temperature ( $^{\circ}\text{C}$ ) -----	62	1.3- 30.5	13.0- 25.5	19.2(15.8)
Turbidity (NTU) -----	59	0.5-11600	22-3850	1500(15.8)
Oxygen, dissolved (mg/L) -----	41	0.80- 19.0	0.80- 7.30	6.70(15.8)
Biochemical oxygen demand (mg/L) -----	13	0.5- 8.3	5.2- 6.0	6.0(15.8)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	32	92- 1430	339- 339	339(10.4)
Calcium, dissolved (mg/L) -----	32	16.0- 192	65.0- 65.0	65.0(10.4)
Magnesium, dissolved (mg/L)-----	32	5.0- 242	42.9- 42.9	42.9(10.4)
Sodium, dissolved (mg/L) -----	34	12.2- 1230	350- 350	350(10.4)
Bicarbonate (mg/L)-----	36	15- 913	354- 354	354(10.4)
Carbonate (mg/L) -----	10	0.5- 26.0	12.0- 12.0	12.0(10.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	36	13- 748	310- 310	310(10.4)
Sulfate, dissolved (mg/L) -----	34	17- 2780	782- 782	782(10.4)
Chloride, dissolved (mg/L) -----	34	1.8- 126	5.9- 5.9	5.9(10.4)
Fluoride, dissolved (mg/L) -----	32	0.2- 1.5	0.4- 0.4	0.4(10.4)
Dissolved solids, calculated (mg/L) -----	32	184- 4820	1610-1610	1610(10.4)
Sediment, total suspended (mg/L) -----	49	0.4-22600	25.8- 25.8	25.8(10.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	21	0.01- 0.43	-----	0.04(2.4)
Nitrogen, total ammonia (mg/L as N) -----	35	0.01- 0.21	-----	0.02(5.4)
Phosphorus, total (mg/L as P)-----	38	0.015- 3.7	-----	0.090(5.4)
Phosphorus, total ortho (mg/L as P)-----	42	0.002- 2.5	-----	0.041(5.4)
Iron, total recoverable (mg/L)-----	20	0.02- 0.75	-----	0.34(2.4)
Manganese, total recoverable (mg/L)-----	17	0.010- 0.37	-----	0.054(2.4)

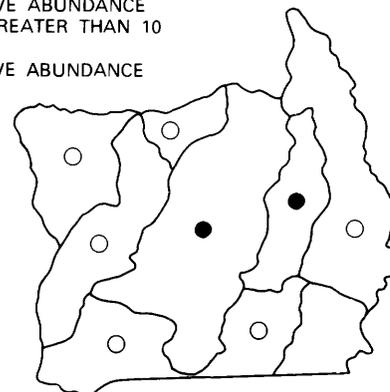
Ecological summary:

Prefers sodium sulfate waters; and fine to medium gravels (0.2 to 3 cm) in medium streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 2,500 ft). Tolerates considerable sediment and turbidity. Summer (July) dominant.

Distribution summary:

Widely distributed in the study area. Prefers Mizpah and Pumpkin Creeks.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *ASTERIONELLA FORMOSA* HASS.

Biotype(s):

*Asterionella formosa* Hass. var. *formosa*

Reference:

Patrick and Reimer, 1966 (p. 159; pl. 9, figs. 1-3)

Herbarium slide number:

1-2-4

Mean percent relative abundance:

0.1

Percent occurrence:

8.6

Abundance-occurrence index:

0.6

Preferred percent occurrence:

0.1

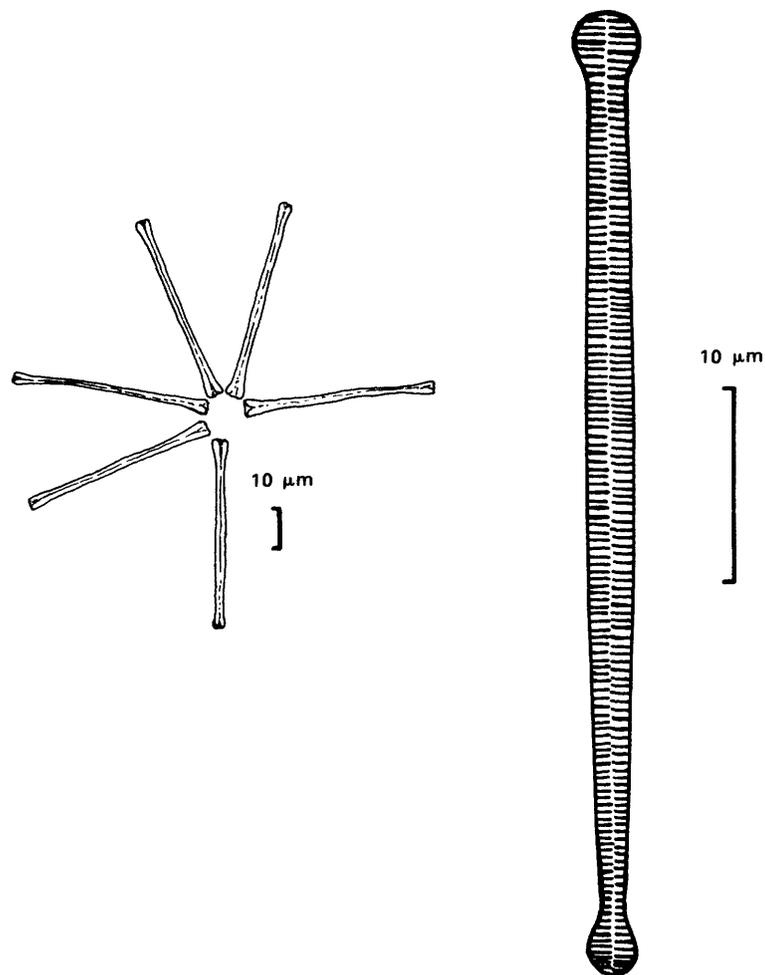
Maximum percent relative abundance:

15.2

Station number: 51

Date: undated

Type of collection: A



Description:

Striae, 24-27 in 10  $\mu\text{m}$ . Length, 50.0  $\mu\text{m}$ . Width, 3.8  $\mu\text{m}$ . A slender, heteropolar diatom without a raphe. Distinguished from species of *Synedra* and *Fragilaria* by frustules with ends of unequal size and by the formation of star-shaped colonies (see drawing).

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	18	292–1150	-----	705(3.2)
pH (units)	17	7.70– 8.48	-----	8.48(3.2)
Temperature ( $^{\circ}\text{C}$ )	16	2.0– 23.8	-----	13.4(3.2)
Turbidity (NTU)	16	0.8– 94	-----	3.3(3.2)
Oxygen, dissolved (mg/L)	12	8.00– 12.8	-----	11.7(0.6)
Biochemical oxygen demand (mg/L)	6	1.8– 3.3	-----	1.8(0.6)
Hardness, total (mg/L $\text{CaCO}_3$ )	10	145– 424	-----	359(0.6)
Calcium, dissolved (mg/L)	10	33.2– 77.0	-----	65.2(0.6)
Magnesium, dissolved (mg/L)	10	15.1– 62.0	-----	47.7(0.6)
Sodium, dissolved (mg/L)	11	9.5– 58.0	-----	46.2(0.6)
Bicarbonate (mg/L)	12	151– 381	-----	273(0.6)
Carbonate (mg/L)	4	4.8– 7.0	-----	4.8(0.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	12	124– 312	-----	232(0.6)
Sulfate, dissolved (mg/L)	11	43– 308	-----	211(0.6)
Chloride, dissolved (mg/L)	11	1.6– 4.8	-----	4.2(0.6)
Fluoride, dissolved (mg/L)	11	0.1– 0.6	-----	0.4(0.6)
Dissolved solids, calculated (mg/L)	10	254– 783	-----	653(0.6)
Sediment, total suspended (mg/L)	18	0.9– 310	-----	4.2(3.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	8	0.01– 0.29	-----	0.29(0.8)
Nitrogen, total ammonia (mg/L as N)	8	0.01– 0.06	-----	0.05(0.8)
Phosphorus, total (mg/L as P)	14	0.010– 0.25	-----	0.020(3.2)
Phosphorus, total ortho (mg/L as P)	12	0.001– 0.15	-----	0.002(3.2)
Iron, total recoverable (mg/L)	11	0.04– 0.35	-----	0.06(3.2)
Manganese, total recoverable (mg/L)	9	0.019– 0.12	-----	0.040(3.2)

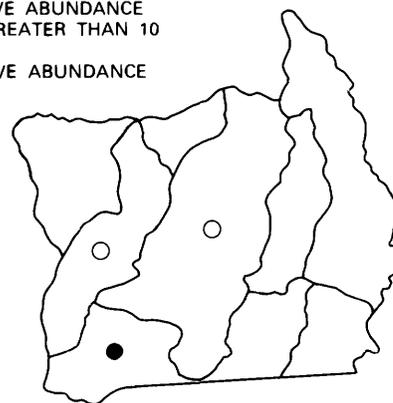
Ecological summary:

Prefers cool freshwater with little turbidity and small concentrations of sodium and suspended sediment. Planktonic, preferably in impoundments, on larger streams (greater than 100 ft<sup>3</sup>/s) at middle elevations (3,000 to 3,500 ft); incidental in streams below impoundments. Spring and fall (May and October) dominant.

Distribution summary:

Found in Tongue River and Rosebud Creek drainages. Seasonally common in the Tongue River Reservoir; incidental in Indian Creek (station 24) and the downstream part of the Tongue River.

EXPLANATION  
 ● PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10  
 ○ PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *COCCONEIS PEDICULUS* EHR.

Biotype(s):

*Cocconeis pediculus* Ehr. var. *pediculus*

Reference:

Patrick and Reimer, 1966 (p. 240; pl. 15, figs. 3-4)

Herbarium slide number:

1-2-5

Mean percent relative abundance:

1.8

Percent occurrence:

50.8

Abundance-occurrence index:

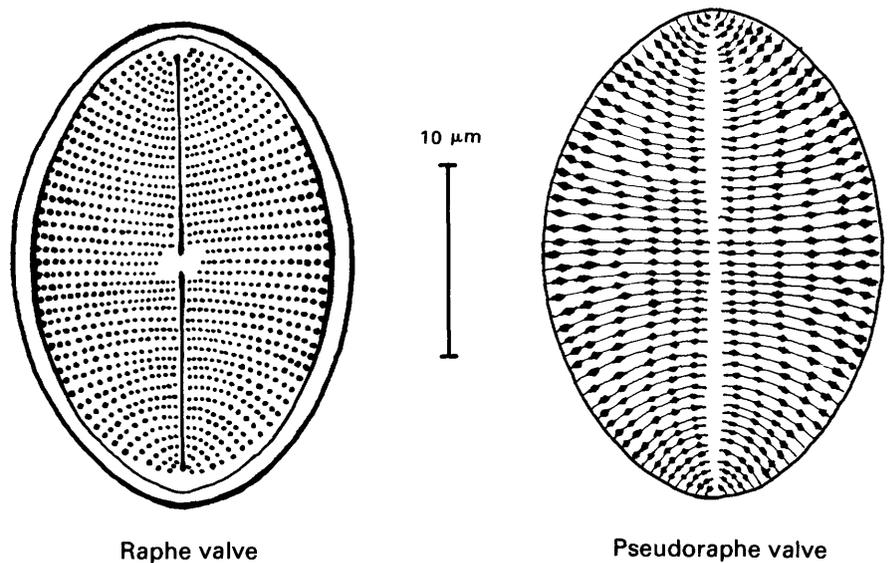
89.5

Preferred percent occurrence:

5.7

Maximum percent relative abundance:

30.3



Station number: 48

Date: August 1, 1979

Type of collection: E

Description:

Striae, 16-18 in 10  $\mu\text{m}$  on raphe valve and 14-16 in 10  $\mu\text{m}$  on pseudoraphe valve. Length, 25.0  $\mu\text{m}$ . Width, 18.0  $\mu\text{m}$ . An elliptical diatom with a highly arched pseudoraphe valve. The raphe valve is concave in contour, presumably adapted for attachment to rounded stems or filaments of aquatic vascular plants and macroalgae. Distinguished from *C. placentula* and varieties by having only a marginal hyaline area on the raphe valve rather than both marginal and sub-marginal hyaline areas.

Water-quality profile:

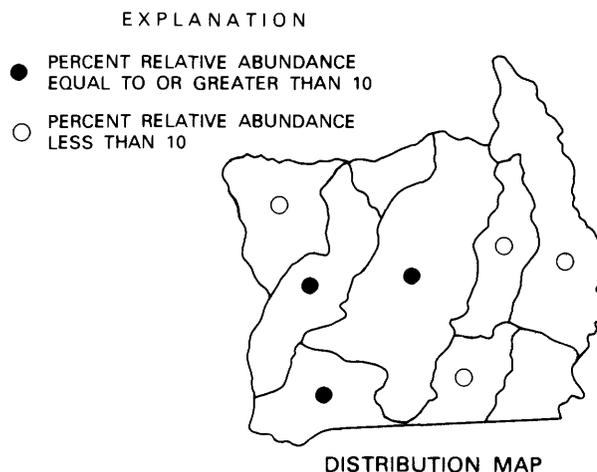
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	145	239-4350	480- 1500	1260(27.4)
pH (units) -----	145	7.50- 8.72	7.91- 8.50	8.40(27.4)
Temperature ( $^{\circ}\text{C}$ ) -----	145	1.7- 30.5	10.5- 25.5	20.0(27.4)
Turbidity (NTU) -----	140	0.5-3250	1.7- 190	56(27.4)
Oxygen, dissolved (mg/L) -----	103	6.78- 15.0	8.70- 10.3	8.70(27.4)
Biochemical oxygen demand (mg/L) -----	39	0.7- 8.9	1.2- 3.3	1.2(23.8)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	85	123-1430	226- 597	597(27.4)
Calcium, dissolved (mg/L) -----	85	16.0- 179	42.8- 69.4	66.4(27.4)
Magnesium, dissolved (mg/L)-----	85	15.1- 242	28.8- 105	105(27.4)
Sodium, dissolved (mg/L) -----	92	9.5- 662	15.8- 82.0	82.0(27.4)
Bicarbonate (mg/L)-----	98	15- 776	45- 514	45(27.4)
Carbonate (mg/L) -----	26	0.5- 36.0	1.0-10.00	1.0(27.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	98	13- 636	39- 421	39(27.4)
Sulfate, dissolved (mg/L) -----	92	17-2390	17- 380	380(27.4)
Chloride, dissolved (mg/L) -----	92	0.4- 174	1.8- 6.3	4.5(27.4)
Fluoride, dissolved (mg/L) -----	88	0.1- 1.5	0.3- 1.3	0.6(27.4)
Dissolved solids, calculated (mg/L) -----	85	184-4020	389- 1020	685(27.4)
Sediment, total suspended (mg/L) -----	139	0.2-8260	3.5- 413	108(27.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	83	0.01- 0.71	0.02- 0.08	0.02(23.8)
Nitrogen, total ammonia (mg/L as N) -----	86	0.01- 0.19	0.01- 0.03	0.03(22.5)
Phosphorus, total (mg/L as P)-----	106	0.010- 3.7	0.012- 0.20	0.014(25.3)
Phosphorus, total ortho (mg/L as P)-----	110	0.001- 2.5	0.001- 0.11	0.002(25.3)
Iron, total recoverable (mg/L)-----	68	0.02- 1.4	0.06- 0.16	0.16(23.8)
Manganese, total recoverable (mg/L)-----	60	0.005- 0.39	0.020-0.045	0.020(23.8)

Ecological summary:

Prefers fresh waters with small sodium content; medium to large streams (greater than 10  $\text{ft}^3/\text{s}$ ); and substrate of coarse sand or larger (greater than 0.3 mm). Tolerates considerable turbidity and suspended sediment. Summer and fall (June to October) dominant. Almost always associated with stands of *Cladophora*.

Distribution summary:

Widespread in the study area. Prefers Rosebud Creek and the Tongue River.



ECOTYPE: *COCCONEIS PLACENTULA* EHR.

Biotype(s):

*C. placentula* Ehr. var. *placentula*  
*C. placentula* var. *euglypta* (Ehr.) Cl.  
\**C. placentula* var. *lineata* (Ehr.) V. H.

Reference:

Patrick and Reimer, 1966 (p. 242; pl. 15,  
figs. 5-6)

Herbarium slide number:

1-2-6

Mean percent relative abundance:

3.9

Percent occurrence:

81.1

Abundance-occurrence index:

315.6

Preferred percent occurrence:

8.6

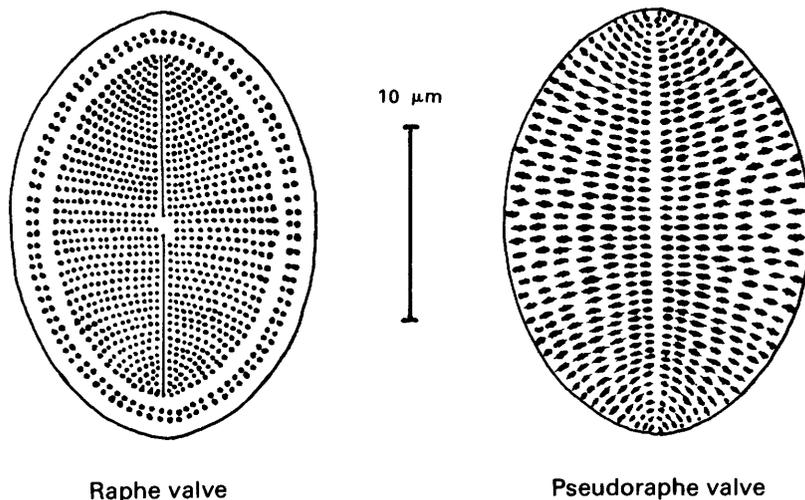
Maximum percent relative abundance:

97.4

Station number: 1

Date: October 19, 1979

Type of collection: C



Description:

Striae, 17-22 in 10  $\mu\text{m}$  on raphe valve and 28-20 in 10  $\mu\text{m}$  on pseudoraphe valve. Length, 22.2  $\mu\text{m}$ . Width, 16.3  $\mu\text{m}$ . Distinguished from *C. pediculus* by the relatively flat pseudoraphe valve and the submarginal hyaline area on the raphe valve. The varieties of *C. placentula* may prove to be different phenotypic expressions of the same genotype. Distinguishing variety *euglypta* from variety *lineata* is often difficult, particularly in mixed populations, where they tend to intergrade.

Water-quality profile:

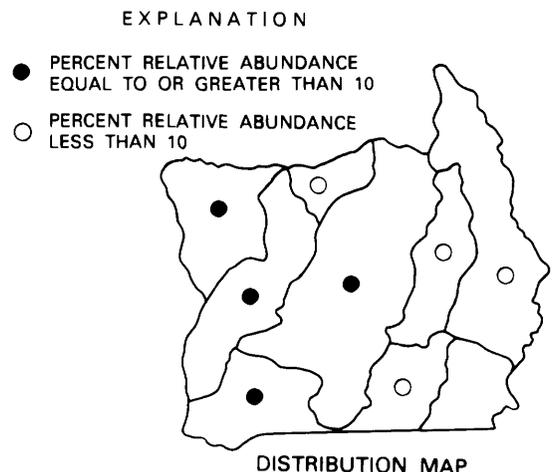
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	245	239-11000	462- 5080	1300(97.4)
pH (units) -----	244	7.50- 8.80	7.50- 8.64	8.01(97.4)
Temperature ( $^{\circ}\text{C}$ ) -----	243	1.0- 30.2	3.9- 23.5	10.1(97.4)
Turbidity (NTU) -----	240	0.5- 435	0.6- 33	0.6(97.4)
Oxygen, dissolved (mg/L) -----	171	4.52- 15.3	6.88- 11.7	9.02(97.4)
Biochemical oxygen demand (mg/L) -----	65	0.5- 8.9	0.8- 7.8	1.1(97.4)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	147	124- 3490	236- 2400	499(97.1)
Calcium, dissolved (mg/L) -----	147	27.4- 330	49.7- 187	79.6(97.1)
Magnesium, dissolved (mg/L)-----	147	13.5- 645	25.7- 467	72.6(97.1)
Sodium, dissolved (mg/L) -----	157	9.1- 1950	18.3- 662	133(97.1)
Bicarbonate (mg/L)-----	164	15- 816	226- 754	534(97.1)
Carbonate (mg/L) -----	38	0.5- 38.4	5.0- 28.0	5.0(24.9)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	164	13- 669	199- 618	438(97.1)
Sulfate, dissolved (mg/L) -----	157	17- 6900	38- 3150	304(97.1)
Chloride, dissolved (mg/L) -----	157	0.4- 174	1.2- 45.6	6.0(97.1)
Fluoride, dissolved (mg/L) -----	152	0.04- 1.7	0.1- 1.3	1.3(97.1)
Dissolved solids, calculated (mg/L) -----	147	184-10400	398- 4650	1130(97.1)
Sediment, total suspended (mg/L) -----	228	0.2- 893	0.2- 46.6	0.4(97.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	125	0.01- 0.80	0.01- 0.53	0.01(94.0)
Nitrogen, total ammonia (mg/L as N) -----	142	0.01- 0.57	0.01- 0.11	0.01(88.0)
Phosphorus, total (mg/L as P)-----	169	0.010- 0.62	0.010-0.088	0.010(94.0)
Phosphorus, total ortho (mg/L as P)-----	173	0.001- 0.52	0.001- 0.12	0.002(97.1)
Iron, total recoverable (mg/L)-----	99	0.02- 2.1	0.02- 0.63	0.02(97.1)
Manganese, total recoverable (mg/L)-----	87	0.005- 0.41	0.005- 0.39	0.090(76.3)

Ecological summary:

Prefers waters with little turbidity and small concentrations of suspended sediment; coarse sand to fine gravel (0.3 to 10 mm); and smaller streams (0.1 to 10 ft<sup>3</sup>/s) at middle elevations (2,500 to 4,000 ft). Summer and fall (June to October) dominant. Pioneer species; colonized artificial substrates (Plexiglas plates) at some sites almost to the exclusion of all other taxa.

Distribution summary:

Widespread, with best development in the western part of the study area. This is the fourth most common diatom ecotype in the southern Fort Union coal region.



ECOTYPE: *CYCLOTELLA MENEGHINIANA* KUTZ.

Biotype(s):

*C. cryptica* Reimann, Lewin and Guillard var.  
*cryptica*

\**C. meneghiniana* Kutz. var. *meneghiniana*  
*C. striata* (Kutz.) Grun. var. *striata*

Reference:

Hustedt, 1930b (p. 100; fig. 67)

Herbarium slide number:

1-2-7

Mean percent relative abundance:

1.7

Percent occurrence:

77.6

Abundance-occurrence index:

135.0

Preferred percent occurrence:

3.0

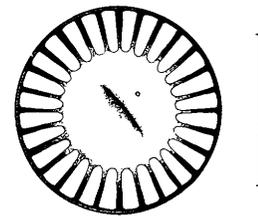
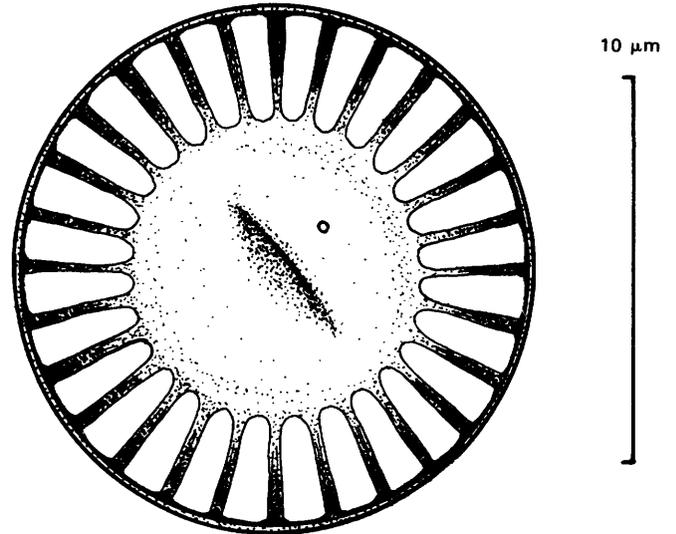
Maximum percent relative abundance:

30.3

Station number: 30

Date: July 7, 1978

Type of collection: E



Description:

Striae, 8 in 10  $\mu\text{m}$ . Diameter, 13.8  $\mu\text{m}$ . A single isolated pore near midvalve. This is a small to medium *Cyclotella* with a distinctive "scallop" edge. Diameter, number of central pores, pattern of the central area, and other features are highly variable. Schoeman and Archibald (1980) have synonymized *C. cryptica* with *C. meneghiniana*. Hustedt (1930a, p. 344) indicates that *C. meneghiniana* may be a somewhat less salt-tolerant form of *C. striata*. The only feature distinguishing these two taxa is the submarginal shadow line of *C. striata*.

## Water-quality profile:

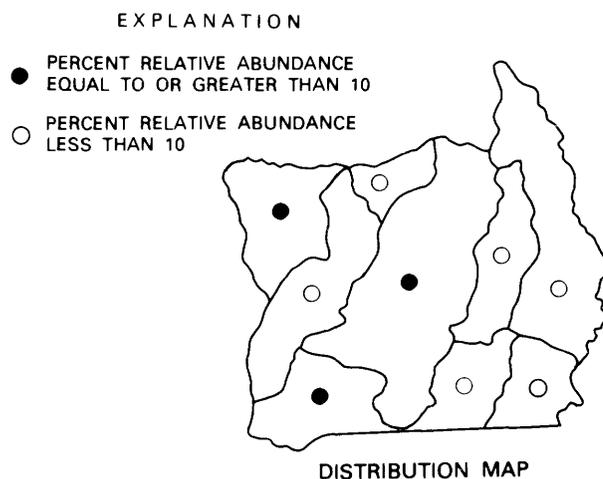
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	244	333-11000	1880- 4200	2840(30.3)
pH (units) -----	244	7.50- 8.80	8.08- 8.49	8.18(30.3)
Temperature ( $^{\circ}\text{C}$ ) -----	243	1.0- 30.5	6.3- 26.7	13.0(30.0)
Turbidity (NTU) -----	240	0.5- 435	0.7- 17	2.2(30.3)
Oxygen, dissolved (mg/L) -----	180	4.52- 19.0	7.04- 14.3	11.1(30.3)
Biochemical oxygen demand (mg/L) -----	70	0.5- 8.9	2.2- 3.6	3.6(25.1)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	143	123- 3490	964- 2300	1080(30.3)
Calcium, dissolved (mg/L) -----	143	16.0- 330	130- 236	130(30.3)
Magnesium, dissolved (mg/L) -----	143	18.3- 645	153- 416	184(30.3)
Sodium, dissolved (mg/L) -----	154	11.5- 1950	280- 480	280(30.3)
Bicarbonate (mg/L) -----	159	15- 816	427- 666	581(30.3)
Carbonate (mg/L) -----	42	0.5- 38.4	-----	4.1(7.2)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	159	13- 669	350- 546	476(30.3)
Sulfate, dissolved (mg/L) -----	154	44- 6900	1070- 2590	1070(30.3)
Chloride, dissolved (mg/L) -----	154	0.4- 174	8.0- 36.0	8.0(30.3)
Fluoride, dissolved (mg/L) -----	149	0.04- 1.7	0.1- 1.1	0.6(30.3)
Dissolved solids, calculated (mg/L) -----	143	184-10400	2250- 4090	2250(30.3)
Sediment, total suspended (mg/L) -----	220	0.2- 893	1.4- 19.3	11.7(30.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	115	0.01- 0.80	0.01- 0.02	0.02(30.3)
Nitrogen, total ammonia (mg/L as N) -----	143	0.01- 0.57	0.01- 0.02	0.02(30.3)
Phosphorus, total (mg/L as P) -----	165	0.010- 0.62	0.020-0.033	0.033(30.3)
Phosphorus, total ortho (mg/L as P) -----	165	0.001- 0.52	0.003-0.017	0.017(30.3)
Iron, total recoverable (mg/L) -----	94	0.02- 2.1	0.10- 0.25	0.25(30.3)
Manganese, total recoverable (mg/L) -----	83	0.005- 0.41	0.025-0.080	0.080(30.3)

## Ecological summary:

Prefers extremely hard, somewhat brackish waters with a large sulfate but small chloride content; and small to medium streams (0 to 10  $\text{ft}^3/\text{s}$ ) at middle elevations (2,500 to 3,500 ft). Substrate indifferent (tychoplanktonic?). Summer and fall (June to October) dominant.

## Distribution summary:

Distributed throughout the study area. Prefers Armells Creek and certain tributaries of the Tongue River.



ECOTYPE: *CYCLOTELLA PSEUDOSTELLIGERA* HUST.

Biotype(s):

*Cyclotella pseudostelligera* Hust. var. *pseudostelligera*

Reference:

Wujek and Rupp, 1980 (p. 10; pl. 1, fig. 10)

Herbarium slide number:

1-2-8

Mean percent relative abundance:

0.4

Percent occurrence:

7.3

Abundance-occurrence index:

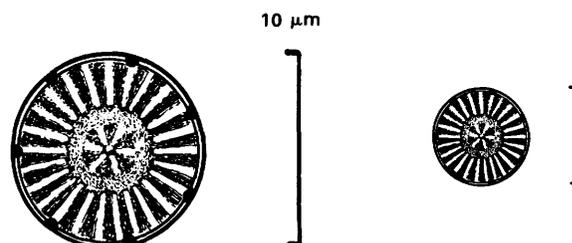
3.2

Preferred percent occurrence:

1.4

Maximum percent relative abundance:

49.2



Station number: 35

Date: July 24, 1979

Type of collection: E

Description:

Striae, 20 in 10  $\mu\text{m}$ . Diameter, 5.0  $\mu\text{m}$ . A very small centric diatom with a central rosette that is morphologically similar to the marginal striae. Distinguished from *C. stelligera* Cl. et Grun. by the presence of marginal spines (strutted processes).

Water-quality profile:

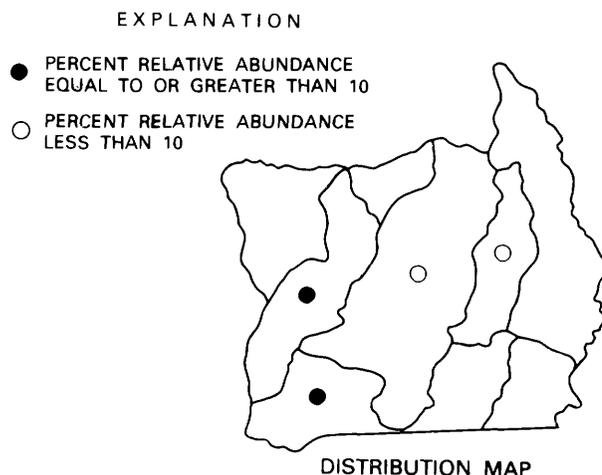
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	23	438- 4350	942- 1400	1260(49.2)
pH (units)	22	7.70- 8.50	8.30- 8.45	8.39(49.2)
Temperature ( $^{\circ}\text{C}$ )	22	3.8- 24.5	16.1- 23.5	23.5(49.2)
Turbidity (NTU)	23	0.8- 132	8.0- 132	132(49.2)
Oxygen, dissolved (mg/L)	15	7.50- 12.8	9.52- 12.8	9.52(26.5)
Biochemical oxygen demand (mg/L)	6	1.0- 3.3	3.0- 3.0	3.0(18.1)
Hardness, total (mg/L $\text{CaCO}_3$ )	9	343- 1430	424- 618	591(49.2)
Calcium, dissolved (mg/L)	9	61.6- 174	65.2- 70.7	69.4(49.2)
Magnesium, dissolved (mg/L)	9	45.0- 242	60.0- 111	101(49.2)
Sodium, dissolved (mg/L)	10	11.7- 662	56.0- 103	75.3(49.2)
Bicarbonate (mg/L)	11	257- 611	257- 460	417(49.2)
Carbonate (mg/L)	3	7.0-10.00	8.4-10.00	10.00(49.2)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	11	211- 501	211- 391	359(49.2)
Sulfate, dissolved (mg/L)	10	69- 2390	308- 441	345(49.2)
Chloride, dissolved (mg/L)	10	2.3- 13.2	4.8- 6.3	6.3(49.2)
Fluoride, dissolved (mg/L)	9	0.3- 0.9	0.3- 0.6	0.6(33.7)
Dissolved solids, calculated (mg/L)	9	550- 4020	757- 1190	1020(49.2)
Sediment, total suspended (mg/L)	22	2.9- 255	12.8- 255	255(49.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	7	0.02- 0.08	0.02- 0.08	0.08(49.2)
Nitrogen, total ammonia (mg/L as N)	14	0.01- 0.05	0.01- 0.03	0.01(49.2)
Phosphorus, total (mg/L as P)	18	0.020- 0.20	0.030- 0.20	0.20(49.2)
Phosphorus, total ortho (mg/L as P)	18	0.003- 0.11	0.003- 0.11	0.11(49.2)
Iron, total recoverable (mg/L)	5	0.07- 0.59	-----	0.17(0.8)
Manganese, total recoverable (mg/L)	4	0.030- 0.10	-----	0.050(0.8)

Ecological summary:

Prefers pH greater than 8.00 and some carbonate ion; and medium to large streams (greater than 10  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 3,500 ft). Tolerates much turbidity and large suspended-sediment concentrations. Spring and summer (May to August) dominant. Tycho-planktonic.

Distribution summary:

Prefers Rosebud Creek and the upstream part of the Tongue River, including the Tongue River Reservoir.



ECOTYPE: *CYMBELLA AFFINIS* KUTZ.

Biotype(s):

- \**C. affinis* Kutz. var. *affinis*
- C. cistula* (Ehr.) Kirchn. var. *cistula*
- C. cymbiformis* Ag. var. *cymbiformis*
- C. cymbiformis* var. *nonpunctata* Font.

Reference:

Patrick and Reimer, 1975 (p. 57; pl. 10, fig. 7)

Herbarium slide number:

1-1-4

Mean percent relative abundance:

2.8

Percent occurrence:

54.6

Abundance-occurrence index:

150.9

Preferred percent occurrence:

8.6

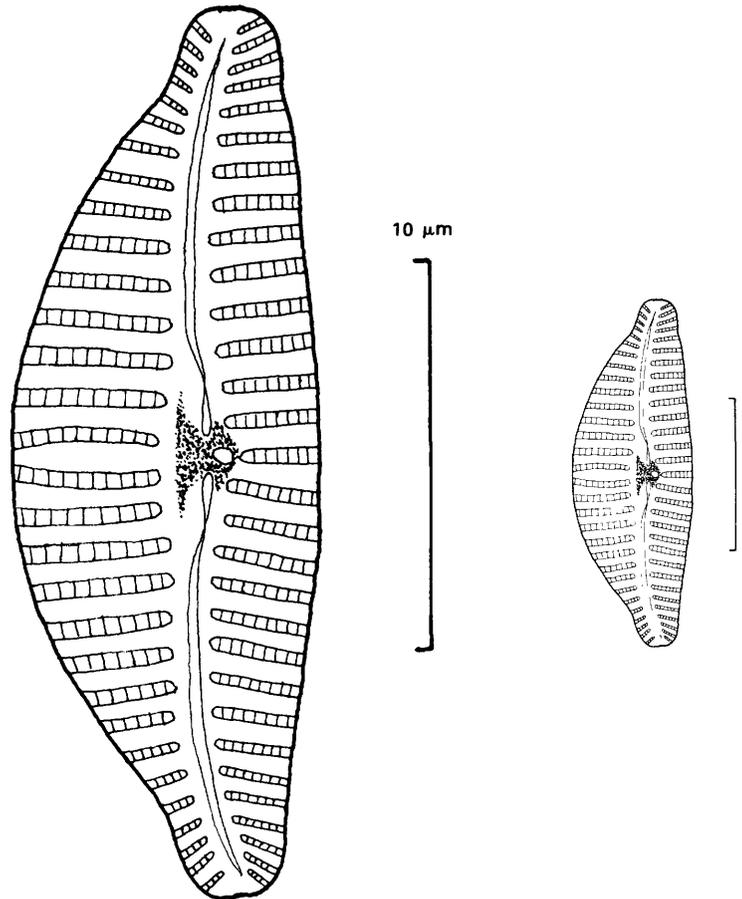
Maximum percent relative abundance:

54.2

Station number: 24

Date: July 17, 1979

Type of collection: E



Description:

Striae, 11 in 10  $\mu\text{m}$  (center). Length, 23.0  $\mu\text{m}$ . Width, 8.0  $\mu\text{m}$ . A medium *Cymbella*, usually with an isolated stigma at the end of the middle stria on the ventral side. Size, shape of ends, and number of isolated stigmata highly variable.

Water-quality profile:

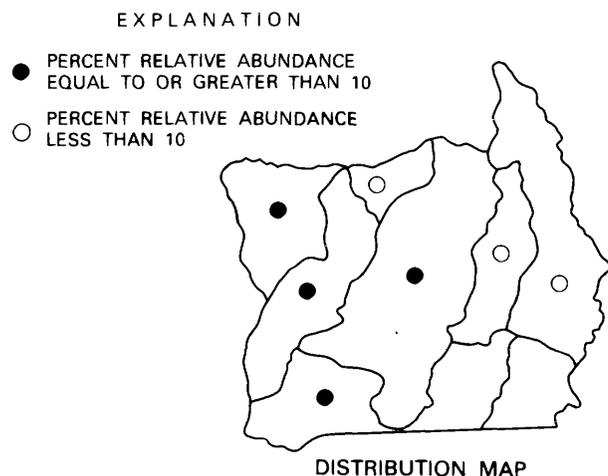
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	161	239-11000	270- 6100	670(54.2)
pH (units)	161	7.62- 8.80	7.63- 8.80	8.39(54.2)
Temperature ( $^{\circ}\text{C}$ )	160	2.0- 30.5	4.9- 23.7	21.2(54.2)
Turbidity (NTU)	156	0.5- 6800	0.8- 53	1.6(54.2)
Oxygen, dissolved (mg/L)	122	5.22- 15.3	5.22- 13.2	9.05(54.2)
Biochemical oxygen demand (mg/L)	46	0.5- 4.2	1.5- 4.2	2.5(46.9)
Hardness, total (mg/L $\text{CaCO}_3$ )	96	123- 3490	124- 2020	343(54.2)
Calcium, dissolved (mg/L)	96	16.0- 328	27.4- 238	62.7(54.2)
Magnesium, dissolved (mg/L)	96	13.5- 645	13.5- 346	45.0(54.2)
Sodium, dissolved (mg/L)	102	9.1- 1950	9.1- 960	11.7(54.2)
Bicarbonate (mg/L)	107	15- 816	111- 661	340(54.2)
Carbonate (mg/L)	23	0.5- 38.4	7.0- 38.4	7.0(54.2)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	107	13- 669	91- 542	290(54.2)
Sulfate, dissolved (mg/L)	102	34- 6900	34- 3350	81(54.2)
Chloride, dissolved (mg/L)	102	1.3- 51.6	1.3- 21.4	2.3(54.2)
Fluoride, dissolved (mg/L)	101	0.1- 1.5	0.1- 1.1	0.6(54.2)
Dissolved solids, calculated (mg/L)	96	184-10400	196- 5560	550(54.2)
Sediment, total suspended (mg/L)	149	0.6- 323	0.8- 131	2.9(54.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	84	0.01- 0.80	0.03- 0.71	0.03(44.3)
Nitrogen, total ammonia (mg/L as N)	90	0.01- 0.22	0.01- 0.09	0.05(54.2)
Phosphorus, total (mg/L as P)	112	0.010- 0.62	0.020- 0.16	0.020(54.2)
Phosphorus, total ortho (mg/L as P)	111	0.001- 0.52	0.002-0.046	0.007(54.2)
Iron, total recoverable (mg/L)	68	0.02- 2.1	0.02- 2.1	0.17(54.2)
Manganese, total recoverable (mg/L)	61	0.005- 0.37	0.010- 0.27	0.050(54.2)

Ecological summary:

Broad ecological amplitude. Seems to prefer fresh, calcium bicarbonate waters; small to medium streams (0.1 to 100  $\text{ft}^3/\text{s}$ ) at middle elevations (2,500 to 4,000 ft); and fine gravels or larger (greater than 0.2 cm diameter). Tolerates some turbidity and suspended sediment. No clear seasonal preference.

Distribution summary:

Widespread. Prefers Rosebud Creek and the Tongue River drainages. The one sample from the downstream part of Armells Creek (station 11) in which the ecotype accounted for more than 10 percent relative abundance (29.7) probably was affected by Yellowstone River irrigation return flows (Klarich and others, 1980).



ECOTYPE: *CYMBELLA MICROCEPHALA* GRUN.

Biotype(s):

*C. microcephala* Grun. var. *microcephala*

Reference:

Patrick and Reimer, 1975 (p. 33; pl. 4,  
figs. 12a-13b)

Herbarium slide number:

1-2-10

Mean percent relative abundance:

0.5

Percent occurrence:

24.3

Abundance-occurrence index:

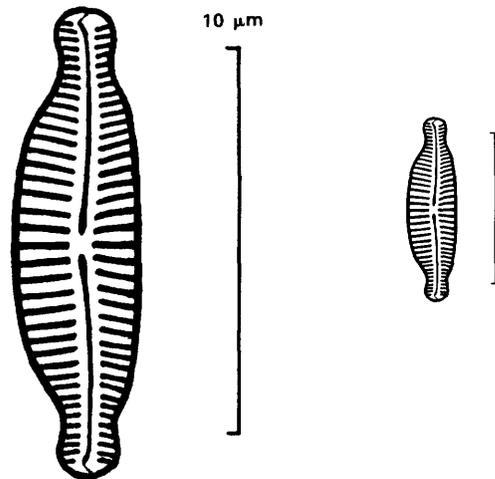
13.1

Preferred percent occurrence:

1.4

Maximum percent relative abundance:

38.6



Station number: 31

Date: July 12, 1979

Type of collection: E

Description:

Striae, 24-32 in 10  $\mu\text{m}$ . Length, 12.2  $\mu\text{m}$ . Width, 3.4  $\mu\text{m}$ . A very small species of *Cymbella*. Distinguished from very small species of *Navicula* by the slightly eccentric raphe and subtle asymmetry on either side of the transapical axis. Distinguished from *Cymbella* sp. X by the much broader apices.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	76	292-4350	480- 1880	1580(38.6)
pH (units) -----	76	7.62- 8.80	7.91- 8.63	8.55(38.6)
Temperature ( $^{\circ}\text{C}$ ) -----	75	3.8- 25.9	15.2- 22.8	20.9(38.6)
Turbidity (NTU) -----	74	0.5- 435	0.8- 11	0.8(38.6)
Oxygen, dissolved (mg/L) -----	57	5.22- 13.6	8.08- 13.2	10.5(38.6)
Biochemical oxygen demand (mg/L) -----	19	0.7- 3.5	-----	1.9(8.7)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	48	145-1430	226- 764	764(38.6)
Calcium, dissolved (mg/L) -----	48	33.2- 192	41.8- 60.0	47.8(38.6)
Magnesium, dissolved (mg/L)-----	48	15.1- 242	28.8- 156	156(38.6)
Sodium, dissolved (mg/L) -----	52	9.5- 662	15.8- 199	108(38.6)
Bicarbonate (mg/L)-----	54	151- 816	281- 564	393(38.6)
Carbonate (mg/L) -----	14	0.5- 38.4	18.0- 22.0	22.0(38.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	54	124- 669	230- 462	358(38.6)
Sulfate, dissolved (mg/L) -----	52	17-2390	17- 617	617(38.6)
Chloride, dissolved (mg/L) -----	52	1.2- 88.9	1.8- 8.2	7.5(38.6)
Fluoride, dissolved (mg/L) -----	51	0.1- 1.3	0.4- 1.3	0.4(38.6)
Dissolved solids, calculated (mg/L) -----	48	254-4020	389- 1550	1350(38.6)
Sediment, total suspended (mg/L) -----	69	0.2- 893	0.8- 22.0	0.9(38.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	43	0.01- 0.80	0.06- 0.41	0.41(17.0)
Nitrogen, total ammonia (mg/L as N) -----	48	0.01- 0.22	0.03- 0.06	0.06(17.0)
Phosphorus, total (mg/L as P)-----	53	0.010- 0.60	0.020-0.040	0.030(38.6)
Phosphorus, total ortho (mg/L as P)-----	52	0.001- 0.38	0.002-0.020	0.008(38.6)
Iron, total recoverable (mg/L)-----	31	0.02- 1.1	0.02- 0.36	0.06(38.6)
Manganese, total recoverable (mg/L)-----	28	0.005- 0.23	0.010-0.045	0.010(38.6)

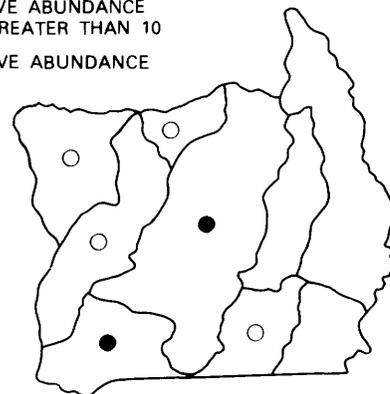
Ecological summary:

Prefers alkaline waters containing some carbonate ion; small streams (0.1 to 10 ft<sup>3</sup>/s) at middle elevations (3,000 to 3,500 ft); and fine gravel (0.2- to 1-cm diameter). Sensitive to suspended sediment and turbidity. Summer (July and August) dominant.

Distribution summary:

Distributed throughout the western part of the study area; conspicuously absent from downstream reaches of the Powder River drainage. Largest populations from small tributaries of the Tongue River.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *CYMBELLA PUSILLA* GRUN.

Biotype(s):

*C. pusilla* Grun. var. *pusilla*

Reference:

Patrick and Reimer, 1975 (p. 25; pl. 3, fig. 18)

Herbarium slide number:

1-2-11

Mean percent relative abundance:

0.4

Percent occurrence:

26.2

Abundance-occurrence index:

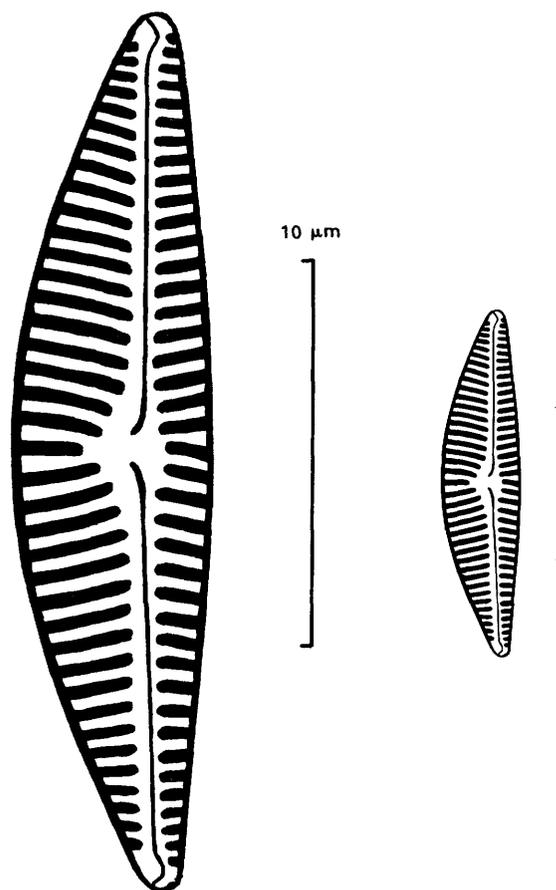
11.7

Preferred percent occurrence:

0.8

Maximum percent relative abundance:

20.7



Station number: 30

Date: September 30, 1979

Type of collection: E

Description:

Striae, 16-20 in 10  $\mu\text{m}$ . Length, 22.8  $\mu\text{m}$ . Width, 5.0  $\mu\text{m}$ . A small species of *Cymbella* without set-off ends. Distinguished by the shortened central striae on both the dorsal and ventral sides.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	84	1210-11000	2930- 6400	6400(20.7)
pH (units) -----	84	7.62- 8.80	8.06- 8.50	8.22(20.7)
Temperature ( $^{\circ}\text{C}$ )-----	85	1.3- 30.5	1.3- 18.0	15.8(20.7)
Turbidity (NTU)-----	84	0.7- 435	1.9- 17	1.9(20.7)
Oxygen, dissolved (mg/L)-----	58	4.52- 19.0	4.52- 12.3	12.1(20.7)
Biochemical oxygen demand (mg/L)-----	14	1.5- 3.6	-----	1.6(6.2)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	53	123- 3490	736- 2610	2610(20.7)
Calcium, dissolved (mg/L)-----	53	16.0- 330	113- 224	224(20.7)
Magnesium, dissolved (mg/L)-----	53	20.0- 645	172- 496	496(20.7)
Sodium, dissolved (mg/L)-----	57	133- 1950	350- 949	949(20.7)
Bicarbonate (mg/L)-----	58	198- 913	547- 913	579(20.7)
Carbonate (mg/L)-----	16	0.5- 38.4	-----	19.0(3.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	58	162- 748	448- 748	475(20.7)
Sulfate, dissolved (mg/L)-----	57	304- 6900	1260- 3930	3930(20.7)
Chloride, dissolved (mg/L)-----	57	2.2- 126	8.1- 29.1	29.1(20.7)
Fluoride, dissolved (mg/L)-----	54	0.04- 1.7	0.5- 0.6	0.6(20.7)
Dissolved solids, calculated (mg/L)-----	53	1130-10400	2450- 6210	6210(20.7)
Sediment, total suspended (mg/L)-----	77	0.4- 893	1.3- 10.7	1.3(20.7)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	34	0.01- 0.71	-----	0.02(6.4)
Nitrogen, total ammonia (mg/L as N)-----	54	0.01- 0.57	0.17- 0.17	0.17(14.0)
Phosphorus, total (mg/L as P)-----	57	0.010- 0.62	0.010-0.030	0.010(20.7)
Phosphorus, total ortho (mg/L as P)-----	58	0.001- 0.52	0.008-0.018	0.008(14.0)
Iron, total recoverable (mg/L)-----	30	0.02- 1.1	0.15- 0.25	0.18(20.7)
Manganese, total recoverable (mg/L)-----	25	0.005- 0.41	0.41- 0.41	0.41(14.0)

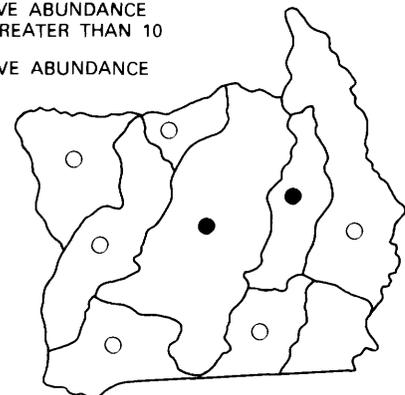
Ecological summary:

Prefers extremely hard, brackish water with large concentrations of sulfate and some chloride; and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) at lower to middle elevations (less than 4,000 ft). Absent from substrates finer than coarse sand (less than 0.3-mm diameter). Late summer and early fall (August to October) dominant.

Distribution summary:

Widespread. Prefers Mizpah Creek and downstream tributaries of the Tongue River.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



ECOTYPE: *CYMBELLA* SPECIES X

Biotype(s):

*C. sp. X* var. *X*

Reference:

None

Herbarium slide number:

1-2-9

Mean percent relative abundance:

0.1

Percent occurrence:

3.0

Abundance-occurrence index:

0.4

Preferred percent occurrence:

0.8

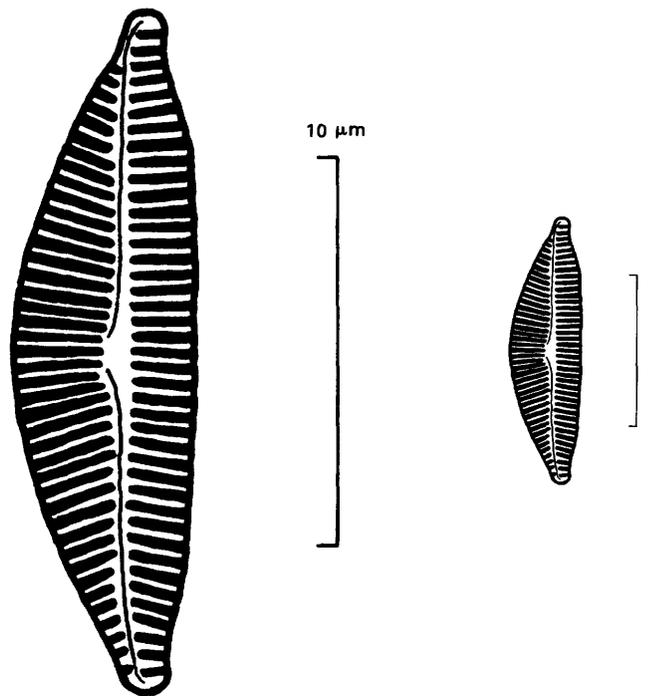
Maximum percent relative abundance:

18.6

Station number: 40

Date: August 21, 1979

Type of collection: E



Description:

Striae, 22-24 in 10  $\mu\text{m}$ . Length, 17.5  $\mu\text{m}$ . Width, 4.7  $\mu\text{m}$ . This is a small *Cymbella* with fine striae and protracted, sub-capitate ends. Some specimens have a central indentation on the ventral margin. C. W. Reimer (Academy of Natural Sciences of Philadelphia, written commun., 1981) indicates that this taxon may be a variation of *C. ruttneri* Hust., distinguished from the nominate variety by the "odd shape of the ends." J. C. Kingston (Limnological Research Center, Univ. of Minnesota, written commun., 1981) thinks it is closer to *C. fonticola* Hust., and he proposes to name it in the near future as a new species or variety.

Water-quality profile:

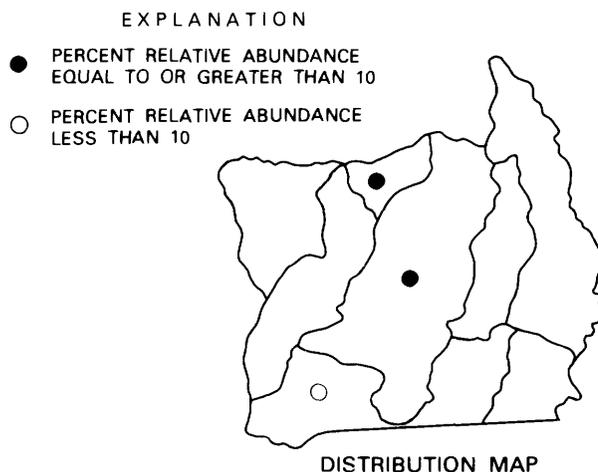
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	10	2580– 3700	2770– 3700	2950(18.6)
pH(units)-----	10	7.84– 8.60	7.84– 8.38	8.38(18.6)
Temperature ( $^{\circ}\text{C}$ ) -----	10	3.7– 24.5	3.7– 24.4	24.4(18.6)
Turbidity (NTU) -----	10	2.8– 32	2.8– 11	11(18.6)
Oxygen, dissolved (mg/L) -----	7	5.22– 12.6	5.22– 12.6	10.9(18.6)
Biochemical oxygen demand (mg/L)-----	0	-----	-----	-----
Hardness, total (mg/L $\text{CaCO}_3$ )-----	7	441– 1350	441– 1350	441(18.6)
Calcium, dissolved (mg/L)-----	7	54.3– 183	54.3– 183	54.3(18.6)
Magnesium, dissolved (mg/L)-----	7	72.0– 217	73.8– 217	73.8(18.6)
Sodium, dissolved (mg/L)-----	8	428– 538	480– 538	538(18.6)
Bicarbonate (mg/L)-----	8	464– 608	472– 608	472(18.6)
Carbonate (mg/L)-----	1	5.0– 5.0	-----	5.0(2.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	8	387– 498	387– 498	387(18.6)
Sulfate, dissolved (mg/L)-----	8	1080– 1940	1110– 1940	1110(18.6)
Chloride, dissolved (mg/L)-----	8	12.0– 43.1	21.4– 43.1	43.1(18.6)
Fluoride, dissolved (mg/L)-----	8	0.5– 0.8	0.6– 0.7	0.7(18.6)
Dissolved solids, calculated (mg/L)-----	7	2190– 3430	2290– 3430	2290(18.6)
Sediment, total suspended (mg/L)-----	10	2.8– 55.1	2.8– 17.5	17.5(18.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	7	0.07– 0.71	0.43– 0.62	0.47(18.6)
Nitrogen, total ammonia (mg/L as N)-----	9	0.01– 0.09	0.02– 0.04	0.04(18.6)
Phosphorus, total (mg/L as P) -----	8	0.010–0.080	0.010–0.020	0.020(18.6)
Phosphorus, total ortho (mg/L as P) -----	8	0.003–0.032	0.005–0.006	0.006(18.6)
Iron, total recoverable (mg/L)-----	3	0.08– 0.35	0.08– 0.28	0.28(18.6)
Manganese, total recoverable (mg/L)-----	2	0.065– 0.10	0.10– 0.10	0.10(18.6)

Ecological summary:

Prefers brackish, sodium sulfate waters with relatively large concentrations of chloride and inorganic nitrogen; gravel-size substrates or larger (greater than 1-cm diameter); and small streams (0.1 to 1.0  $\text{ft}^3/\text{s}$ ). Eurythermal from 3 to 25  $^{\circ}\text{C}$ . Indifferent to elevation. Tolerates some turbidity and suspended sediment. Late summer and early fall (August to October) dominant.

Distribution summary:

Found in the Tongue River drainage and Sweeney Creek (station 40). Best population development in Sweeney Creek and Bear Creek near Otter (station 13).



ECOTYPE: *DIATOMA TENUE* AG.

Biotype(s):

\**D. tenue* Ag. var. *tenue*  
*D. tenue* var. *elongatum* Lyngb.

Reference:

Patrick and Reimer, 1966 (p. 108; pl. 2, fig. 5)

Herbarium slide number:

1-2-12

Mean percent relative abundance:

1.6

Percent occurrence:

36.5

Abundance-occurrence index:

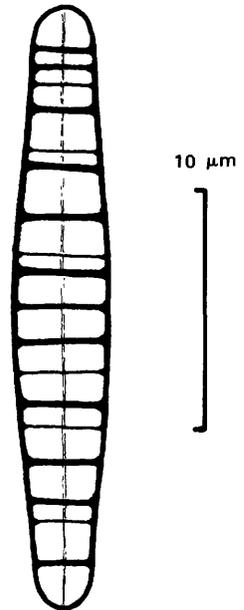
58.3

Preferred percent occurrence:

4.3

Maximum percent relative abundance:

74.8



Station number: 11

Date: May 13, 1979

Type of collection: E

Description:

Costae, 6-9 in 10  $\mu\text{m}$ . Length, 25.0  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . A very slender species of *Diatoma*. Distinguished from *D. vulgare* by the narrow frustules; not more than 5  $\mu\text{m}$  wide in valve view.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	106	362-6400	1880- 5200	5200(74.8)
pH(units) -----	106	7.62- 8.80	7.90- 8.35	8.05(74.8)
Temperature ( $^{\circ}\text{C}$ )-----	105	1.0- 30.2	5.1- 27.3	15.8(74.8)
Turbidity (NTU) -----	105	0.5-4200	2.3- 18	16(74.8)
Oxygen, dissolved (mg/L) -----	78	5.22- 14.3	8.08- 12.3	9.40(74.8)
Biochemical oxygen demand (mg/L) -----	32	0.5- 4.2	1.0- 2.5	1.9(74.8)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	67	181-3320	635- 1610	1440(74.8)
Calcium, dissolved (mg/L) -----	67	38.6- 330	60.0- 222	184(74.8)
Magnesium, dissolved (mg/L)-----	67	20.6- 605	78.0- 256	238(74.8)
Sodium, dissolved (mg/L) -----	72	14.3- 995	199- 820	820(74.8)
Bicarbonate (mg/L)-----	75	15- 816	475- 730	627(74.8)
Carbonate (mg/L) -----	9	0.5- 38.4	-----	22.0(6.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	75	13- 669	389- 598	514(74.8)
Sulfate, dissolved (mg/L) -----	72	93-5450	584- 2850	2610(74.8)
Chloride, dissolved (mg/L) -----	72	0.4- 88.9	8.0- 25.3	25.3(74.8)
Fluoride, dissolved (mg/L) -----	71	0.1- 1.2	0.3- 0.8	0.3(74.8)
Dissolved solids, calculated (mg/L) -----	67	184-7680	1550- 4760	4500(74.8)
Sediment, total suspended (mg/L) -----	101	0.2-3220	1.1- 44.4	44.4(74.8)
Nitrogen, total $\text{NO}_2+\text{NO}_3$ (mg/L as N)-----	54	0.01- 0.80	0.01- 0.66	0.01(74.8)
Nitrogen, total ammonia (mg/L as N) -----	67	0.01- 0.57	0.01- 0.22	0.06(74.8)
Phosphorus, total (mg/L as P)-----	75	0.010- 2.6	0.020-0.060	0.030(74.8)
Phosphorus, total ortho (mg/L as P)-----	74	0.001- 1.8	0.003-0.020	0.013(74.8)
Iron, total recoverable (mg/L)-----	42	0.04- 2.1	0.21- 0.36	0.32(17.9)
Manganese, total recoverable (mg/L)-----	37	0.005- 0.36	0.040- 0.12	0.12(17.9)

Ecological summary:

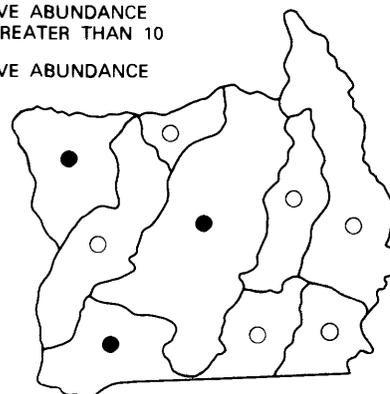
Prefers extremely hard, brackish water with large sodium and sulfate concentrations; coarse sand or larger (greater than 0.3 mm); and medium-size streams (1 to 100 ft<sup>3</sup>/s) at lower elevations (2,501 to 3,000 ft). Tolerates some suspended sediment, turbidity, and chloride. Cool season (October to June) dominant.

Distribution summary:

Distributed throughout the study area.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *DIATOMA VULGARE* BORY

Biotype(s):

\**D. vulgare* Bory var. *vulgare*  
*D. vulgare* var. *breve* Grun.  
*D. vulgare* var. *linearis* V. H.

Reference:

Patrick and Reimer, 1966 (p. 109; pl. 2, fig. 9)

Herbarium slide number:

1-2-13

Mean percent relative abundance:

1.2

Percent occurrence:

31.1

Abundance-occurrence index:

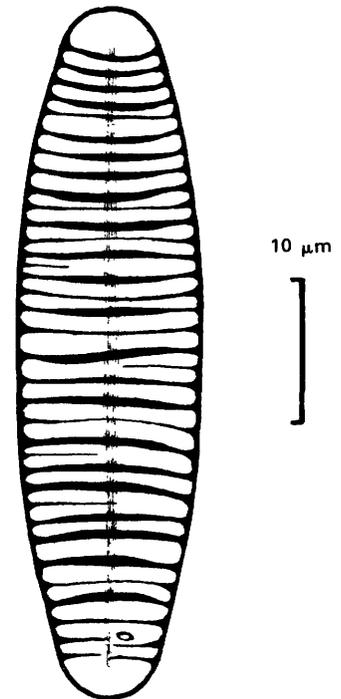
36.5

Preferred percent occurrence:

3.2

Maximum percent relative abundance:

55.5



Station number: 52

Date: October 21, 1975

Type of collection: E

Description:

Costae, 6-8 in 10  $\mu\text{m}$ . Length, 47.5  $\mu\text{m}$ . Width, 13.0  $\mu\text{m}$ . A robust species of *Diatoma*. Distinguished from *D. tenue* by the relatively broad valves, not less than 8  $\mu\text{m}$  wide.

Water-quality profile:

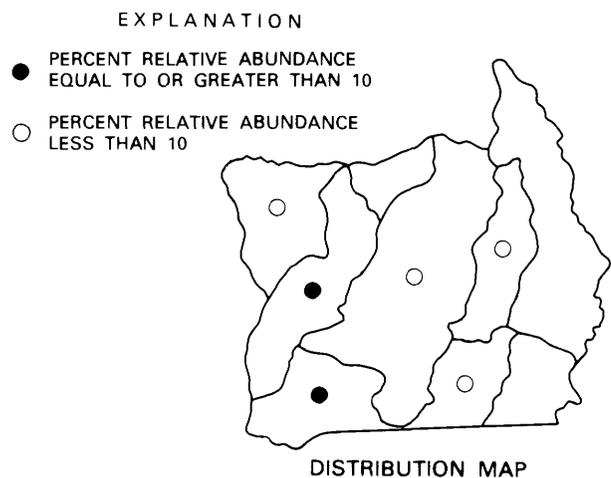
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	82	239- 4350	333- 1030	876(55.5)
pH (units)	81	7.70- 8.72	8.02- 8.50	8.27(55.5)
Temperature ( $^{\circ}\text{C}$ )	82	1.0- 30.5	3.7- 23.5	10.1(55.5)
Turbidity (NTU)	78	0.8- 3250	2.0- 24	4.5(38.5)
Oxygen, dissolved (mg/L)	54	7.60- 13.8	8.00- 13.8	10.2(55.5)
Biochemical oxygen demand (mg/L)	22	0.7- 3.3	1.0- 3.3	3.3(55.5)
Hardness, total (mg/L $\text{CaCO}_3$ )	44	123- 1430	181- 528	392(55.5)
Calcium, dissolved (mg/L)	44	16.0- 174	38.6- 90.0	77.0(55.5)
Magnesium, dissolved (mg/L)	44	13.5- 242	20.6- 74.0	48.5(55.5)
Sodium, dissolved (mg/L)	47	9.1- 662	13.7- 64.0	47.0(55.5)
Bicarbonate (mg/L)	53	15- 776	15- 498	289(55.5)
Carbonate (mg/L)	15	0.5-10.00		3.0(5.3)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	53	13- 636	13- 408	237(55.5)
Sulfate, dissolved (mg/L)	47	34- 2390	77- 320	234(55.5)
Chloride, dissolved (mg/L)	47	1.3- 88.9	2.2- 5.2	3.6(55.5)
Fluoride, dissolved (mg/L)	44	0.1- 1.2	0.2- 0.7	0.3(55.5)
Dissolved solids, calculated (mg/L)	44	184- 4020	184- 844	705(55.5)
Sediment, total suspended (mg/L)	78	0.7- 8260	4.2- 26.0	7.5(55.5)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	45	0.01- 0.43	0.01- 0.25	0.01(38.5)
Nitrogen, total ammonia (mg/L as N)	43	0.01- 0.30	0.01- 0.03	0.03(55.5)
Phosphorus, total (mg/L as P)	62	0.010- 3.7	0.015-0.037	0.015(55.5)
Phosphorus, total ortho (mg/L as P)	61	0.001- 2.5	0.002-0.013	0.003(55.5)
Iron, total recoverable (mg/L)	33	0.04- 0.83	0.08- 0.33	0.12(55.5)
Manganese, total recoverable (mg/L)	29	0.019- 0.12	0.019- 0.12	0.12(55.5)

Ecological summary:

Prefers cool, fresh waters with relatively small concentrations of sodium and sulfate; substrate the size of coarse gravel or larger (greater than 3-cm diameter); and medium to large streams (greater than 1  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 4,000 ft). Late summer to fall (July to October) dominant.

Distribution summary:

Optimum population development in the Rosebud Creek and upstream Tongue River drainages.



ECOTYPE: *DIPLONEIS SMITHII* VAR. *PUMILA* (GRUN.) HUST.

Biotype(s):

*D. smithii* var. *pumila* (Grun.) Hust.

Reference:

Patrick and Reimer, 1966 (p. 411; pl. 38, fig. 4)

Herbarium slide number:

1-2-14

Mean percent relative abundance:

1.1

Percent occurrence:

47.0

Abundance-occurrence index:

51.1

Preferred percent occurrence:

2.4

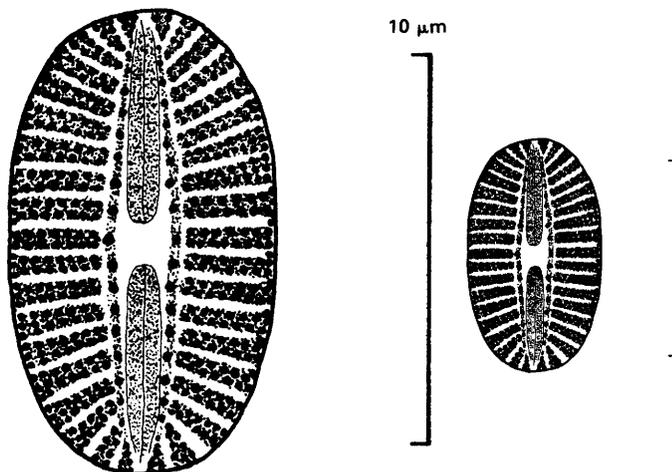
Maximum percent relative abundance:

25.6

Station number: 3

Date: October 7, 1978

Type of collection: E



Description:

Costae, 14-18 in 10  $\mu\text{m}$ . Length, 12.0  $\mu\text{m}$ . Width, 7.0  $\mu\text{m}$ . Between the costae are two rows of alveoli that become three rows toward the valve margin. This feature is readily apparent only under an electron microscope; under the best optical microscopes, certain specimens give the appearance of being lineate or of having a single row of alveoli between the costae. Our specimens are mostly smaller than the usual size range for this taxon. D. W. Blinn (Northern Arizona University, written commun., 1981) reports that brackish-water forms of many diatoms often are smaller than sizes recorded in the literature. This taxon is similar to *D. minima* Hust., except that the "striae" between the costae are not narrower than the costae. It is distinguished from *D. pseudovalis* Hust. and *D. puella* (Schum.) Cl., two other small species of *Diploneis* from the study area, by the fine costae, small central area, and double row of alveoli between the costae.

Water-quality profile:

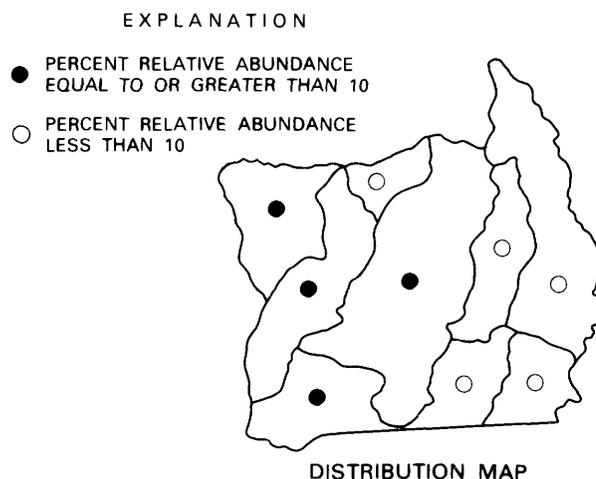
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	157	462-11000	1670- 7030	4050(25.6)
pH (units) -----	157	7.65- 8.80	8.08- 8.62	8.10(25.6)
Temperature ( $^{\circ}\text{C}$ )-----	156	1.0- 30.5	6.2- 23.5	12.7(25.6)
Turbidity (NTU)-----	155	0.7-11600	1.2- 26	5.4(25.6)
Oxygen, dissolved (mg/L)-----	112	5.22- 15.3	7.65- 12.0	11.6(14.6)
Biochemical oxygen demand (mg/L)-----	34	0.5- 8.3	2.5- 7.8	2.5(14.6)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	97	92- 3490	586- 1410	1320(25.6)
Calcium, dissolved (mg/L)-----	97	16.0- 330	69.7- 192	168(25.6)
Magnesium, dissolved (mg/L)-----	97	5.0- 645	81.2- 238	218(25.6)
Sodium, dissolved (mg/L)-----	104	18.3- 1950	131- 1470	580(25.6)
Bicarbonate (mg/L)-----	107	45- 913	492- 623	547(25.6)
Carbonate (mg/L)-----	28	0.5- 38.4	29.0- 29.0	29.0(11.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	107	39- 748	403- 558	449(25.6)
Sulfate, dissolved (mg/L)-----	104	44- 6900	454- 3400	2100(25.6)
Chloride, dissolved (mg/L)-----	104	0.4- 174	4.4- 27.8	14.1(25.6)
Fluoride, dissolved (mg/L)-----	101	0.04- 1.7	0.3- 1.0	0.8(25.6)
Dissolved solids, calculated (mg/L)-----	97	398-10400	1430- 5800	3630(25.6)
Sediment, total suspended (mg/L)-----	142	0.2-22600	2.3- 42.8	11.8(25.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	71	0.01- 0.62	0.01- 0.06	0.01(25.6)
Nitrogen, total ammonia (mg/L as N)-----	97	0.01- 0.30	0.01- 0.11	0.01(14.6)
Phosphorus, total (mg/L as P)-----	109	0.010- 0.62	0.010- 0.11	0.010(25.6)
Phosphorus, total ortho (mg/L as P)-----	110	0.001- 0.52	0.002-0.045	0.002(14.6)
Iron, total recoverable (mg/L)-----	62	0.02- 1.4	0.21- 0.44	0.21(14.6)
Manganese, total recoverable (mg/L)-----	57	0.005- 0.39	0.064- 0.12	0.064(14.6)

Ecological summary:

Prefers brackish waters of large pH (greater than 8.00); coarse sand substrates or larger (greater than 0.3-mm diameter); and small streams (0.1 to 1.0  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 3,500 ft). Eurythermal over the range of 6.2 to 23.5  $^{\circ}\text{C}$ . Tolerates some chloride, suspended sediment, and turbidity. Summer and fall (July to October) dominant.

Distribution summary:

Found throughout the study area. Best population development in the upstream part of Hanging Woman Creek.



ECOTYPE: *ENTOMONEIS PALUDOSA* (W. SM.) REIM.

Biotype(s):

*E. paludosa* (W. Sm.) Reim. var. *paludosa*

Reference:

Patrick and Reimer, 1975 (p. 4; pl. 1, fig. 1)

Herbarium slide number:

1-2-15

Mean percent relative abundance:

0.5

Percent occurrence:

44.3

Abundance-occurrence index:

21.1

Preferred percent occurrence:

0.5

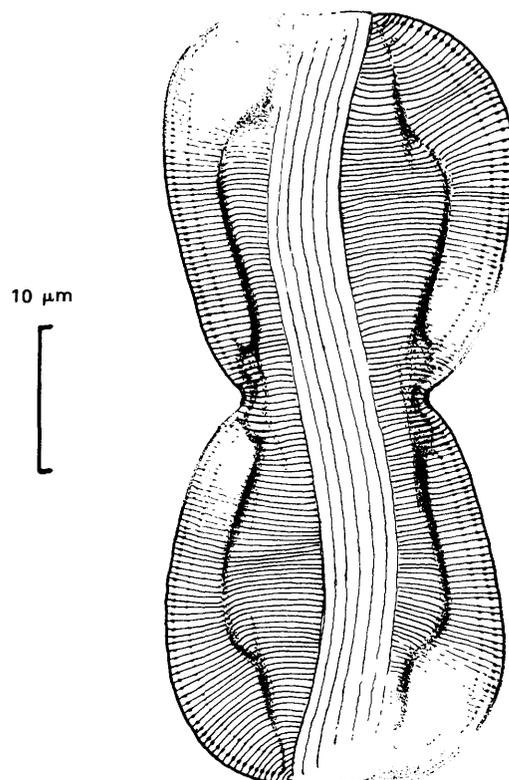
Maximum percent relative abundance:

15.3

Station number: 2

Date: June 17, 1978

Type of collection: E



Description:

Striae, 20-24 in 10  $\mu\text{m}$ . Length, 53.0  $\mu\text{m}$ . Width, 24.5  $\mu\text{m}$ . A large, elegant diatom, almost always appearing in girdle view. Distinguished from the other two Montana species in this genus [*E. alata* (Ehr.) Ehr. and *E. ornata* (J. W. Bail.) Reim.] by the apparently undifferentiated (non-punctate) striae.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	145	1170–11000	2620– 4100	4100(15.3)
pH (units)	145	7.50– 8.80	8.18– 8.21	8.18(15.3)
Temperature ( $^{\circ}\text{C}$ )	146	1.3– 30.5	10.5– 19.0	19.0(15.3)
Turbidity (NTU)	144	0.7– 3250	20– 23	20(15.3)
Oxygen, dissolved (mg/L)	111	4.52– 19.0	6.15– 6.15	6.15(15.3)
Biochemical oxygen demand (mg/L)	44	0.5– 8.9	-----	3.3(6.3)
Hardness, total (mg/L $\text{CaCO}_3$ )	84	123– 3490	-----	1180(6.3)
Calcium, dissolved (mg/L)	84	16.0– 328	-----	152(6.3)
Magnesium, dissolved (mg/L)	84	20.0– 645	-----	195(6.3)
Sodium, dissolved (mg/L)	91	82.8– 1950	-----	505(6.3)
Bicarbonate (mg/L)	94	261– 913	274– 274	274(10.3)
Carbonate (mg/L)	19	0.5– 38.4	-----	5.0(5.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	94	214– 748	225– 225	225(10.3)
Sulfate, dissolved (mg/L)	91	267– 6900	-----	1760(6.3)
Chloride, dissolved (mg/L)	91	2.2– 51.6	-----	12.6(6.3)
Fluoride, dissolved (mg/L)	91	0.04– 1.7	-----	0.9(6.3)
Dissolved solids, calculated (mg/L)	84	1140–10400	-----	3240(6.3)
Sediment, total suspended (mg/L)	131	0.2– 8260	45.6– 45.6	45.6(10.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	69	0.01– 0.71	-----	0.07(5.7)
Nitrogen, total ammonia (mg/L as N)	93	0.01– 0.57	0.02– 0.02	0.02(10.3)
Phosphorus, total (mg/L as P)	99	0.010– 3.7	0.020–0.020	0.020(10.3)
Phosphorus, total ortho (mg/L as P)	96	0.001– 2.5	0.010–0.010	0.010(10.3)
Iron, total recoverable (mg/L)	53	0.02– 2.1	-----	0.34(5.6)
Manganese, total recoverable (mg/L)	46	0.010– 0.41	-----	0.054(5.6)

Ecological summary:

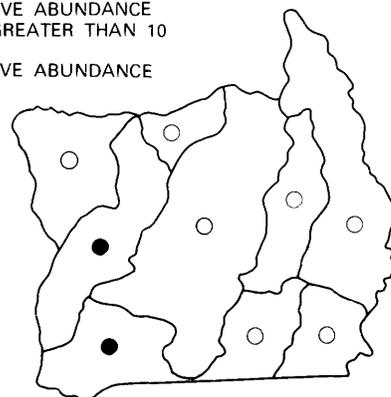
Prefers extremely hard, brackish, sodium sulfate waters; fine to medium gravels (0.2– to 3–cm diameter); and medium streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 3,500 ft). Tolerates some suspended sediment and turbidity and relatively small concentrations of dissolved oxygen. Spring (May and June) dominant.

Distribution summary:

Distributed throughout the study area. Best population development in Hanging Woman Creek and Cow Creek near Colstrip (station 18).

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *EPITHEMIA ADNATA* (KUTZ.) BREB.

Biotype(s):

- E. adnata* (Kutz.) Breb. var. *adnata*
- \**E. adnata* var. *minor* (Perag. & Herib.) Patr.
- E. adnata* var. *porcellus* (Kutz.) Patr.
- E. adnata* var. *proboscidea* (Kutz.) Patr.

Reference:

Patrick and Reimer, 1975 (p. 180; pl. 24, figs. 7-8)

Herbarium slide number:

1-2-16

Mean percent relative abundance:

0.1

Percent occurrence:

10.5

Abundance-occurrence index:

1.2

Preferred percent occurrence:

0.3

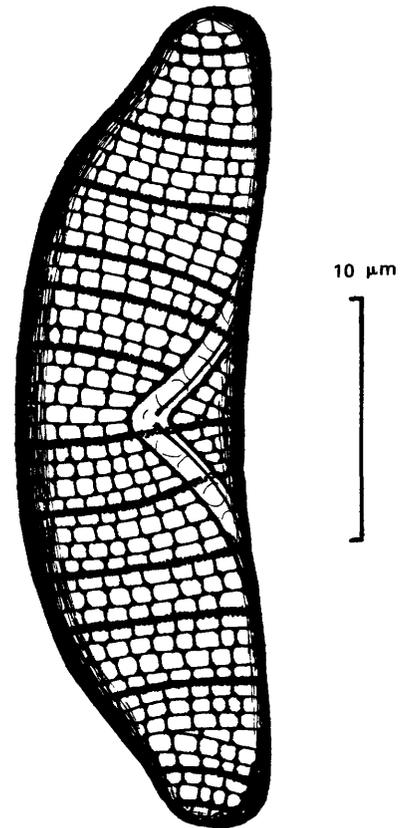
Maximum percent relative abundance:

13.1

Station number: 23

Date: August 24, 1978

Type of collection: E



Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Costae, 3-5 in 10  $\mu\text{m}$ . Length, 34.0  $\mu\text{m}$ . Width, 9.7  $\mu\text{m}$ . This species is extremely variable in size and in the shape of the ends. It is easily distinguished from *E. sorex* in that the central nodule of the raphe is no closer to the dorsal margin than about mid-valve, whereas in *E. sorex* the central nodule lies very close to the dorsal margin. Distinguished from *E. turgida* (Ehr.) Kutz. by having more rows of alveoli between the costae, often more than 4 rather than 2 to 4 as in *E. turgida*.

## Water-quality profile:

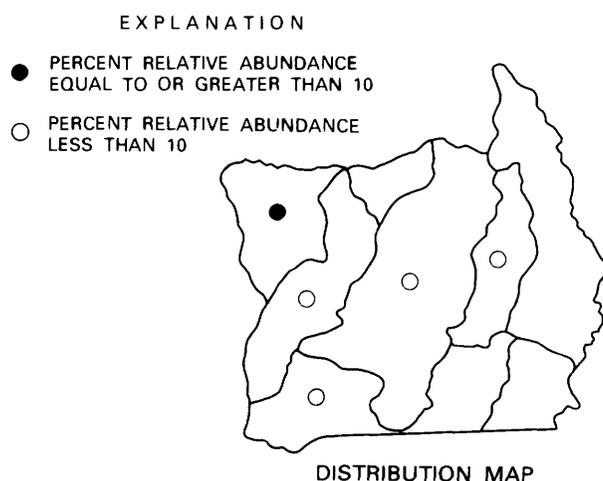
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	26	480- 6400	6400- 6400	6400(13.1)
pH (units) -----	26	7.91- 8.73	8.10- 8.10	8.10(13.1)
Temperature ( $^{\circ}\text{C}$ ) -----	26	2.5- 29.2	23.3- 23.3	23.3(13.1)
Turbidity (NTU) -----	24	0.7- 64	3.5- 3.5	3.5(13.1)
Oxygen, dissolved (mg/L) -----	14	4.52- 14.3	-----	14.3(3.9)
Biochemical oxygen demand (mg/L) -----	3	1.5- 3.6	-----	3.6(3.9)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	17	222- 3320	3320- 3320	3320(13.1)
Calcium, dissolved (mg/L) -----	17	40.0- 330	330- 330	330(13.1)
Magnesium, dissolved (mg/L) -----	17	28.3- 605	605- 605	605(13.1)
Sodium, dissolved (mg/L) -----	17	15.8- 949	665- 665	665(13.1)
Bicarbonate (mg/L) -----	20	171- 798	594- 594	594(13.1)
Carbonate (mg/L) -----	6	0.5- 21.0	-----	11.0(0.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	20	146- 654	487- 487	487(13.1)
Sulfate, dissolved (mg/L) -----	17	17- 4040	4040- 4040	4040(13.1)
Chloride, dissolved (mg/L) -----	17	1.8- 54.6	54.6- 54.6	54.6(13.1)
Fluoride, dissolved (mg/L) -----	15	0.3- 1.7	0.3- 0.3	0.3(13.1)
Dissolved solids, calculated (mg/L) -----	17	389- 6290	6290- 6290	6290(13.1)
Sediment, total suspended (mg/L) -----	24	1.0- 135	4.4- 4.4	4.4(13.1)
Nitrogen, total $\text{NO}_2+\text{NO}_3$ (mg/L as N) -----	6	0.01- 0.37	-----	0.05(0.6)
Nitrogen, total ammonia (mg/L as N) -----	15	0.01- 0.57	0.07- 0.07	0.07(13.1)
Phosphorus, total (mg/L as P) -----	20	0.010- 0.13	0.014-0.014	0.014(13.1)
Phosphorus, total ortho (mg/L as P) -----	21	0.001-0.079	0.010-0.010	0.010(13.1)
Iron, total recoverable (mg/L) -----	12	0.04- 1.4	-----	0.10(3.9)
Manganese, total recoverable (mg/L) -----	10	0.025- 0.41	-----	0.025(3.9)

## Ecological summary:

Preferences sketchy, based on only one occurrence over 10 percent relative abundance. Seems to prefer warm, extremely hard, brackish water with relatively large concentrations of magnesium and sulfate; fine gravel or larger (greater than 0.2-cm diameter); and very small streams (0 to 0.1  $\text{ft}^3/\text{s}$ ) at 2,500 to 3,000 ft elevation. Tolerates some chloride. Summer (June to August) dominant.

## Distribution summary:

Recorded from all hydrologic units except those representing the Powder and Little Powder Rivers. Best population development in the East Fork of Armells Creek near Colstrip (station 23).



ECOTYPE: *EPITHEMIA SOREX* KUTZ.

Biotype(s):

*E. sorex* Kutz. var. *sorex*

Reference:

Patrick and Reimer, 1975 (p. 188; pl. 27, fig. 4)

Herbarium slide number:

1-2-17

Mean percent relative abundance:

0.3

Percent occurrence:

12.2

Abundance-occurrence index:

3.8

Preferred percent occurrence:

0.8

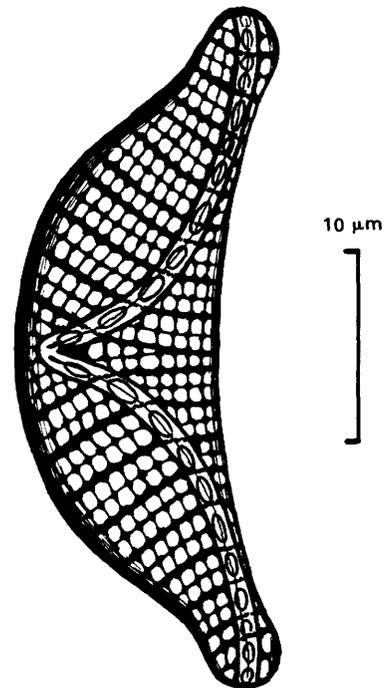
Maximum percent relative abundance:

28.0

Station number: 41

Date: September 24, 1977

Type of collection: E



Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Costae, 5-7 in 10  $\mu\text{m}$ . Length, 28.0  $\mu\text{m}$ . Width, 8.8  $\mu\text{m}$ . A relatively small species of *Epithemia* with fairly constant features. Easily distinguished from *E. adnata* and *E. turgida* in that the central nodule of the raphe occurs very near to the dorsal margin of the valve.

## Water-quality profile:

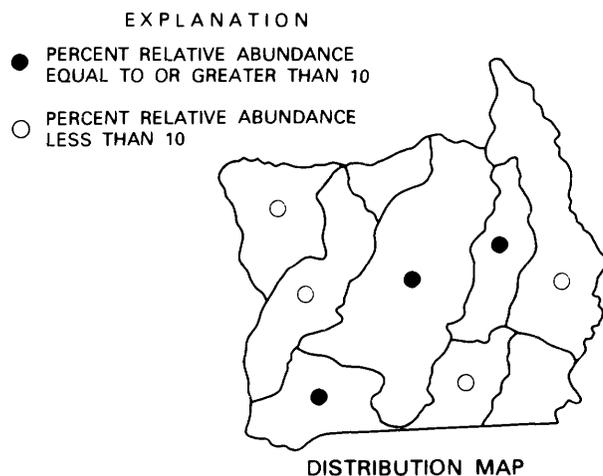
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	35	239–3270	669– 3010	3010(19.0)
pH (units)	35	7.70– 8.59	8.08– 8.39	8.08(19.0)
Temperature ( $^{\circ}\text{C}$ )	35	3.5– 26.0	13.3– 14.3	14.3(19.0)
Turbidity (NTU)	34	0.8– 376	3.2– 7.9	3.6(19.0)
Oxygen, dissolved (mg/L)	24	6.78– 13.1	7.45– 7.45	7.45(19.0)
Biochemical oxygen demand (mg/L)	6	1.2– 3.5	-----	2.1(0.3)
Hardness, total (mg/L $\text{CaCO}_3$ )	18	145–1100	1100– 1100	1100(19.0)
Calcium, dissolved (mg/L)	18	33.2– 143	98.4– 98.4	98.4(19.0)
Magnesium, dissolved (mg/L)	18	15.1– 206	206– 206	206(19.0)
Sodium, dissolved (mg/L)	20	9.5– 396	396– 396	396(19.0)
Bicarbonate (mg/L)	25	151– 712	278– 514	514(19.0)
Carbonate (mg/L)	8	3.0– 24.0	-----	7.0(2.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	25	124– 584	228– 421	421(19.0)
Sulfate, dissolved (mg/L)	20	43–1440	1440– 1440	1440(19.0)
Chloride, dissolved (mg/L)	20	1.2– 174	16.6– 16.6	16.6(19.0)
Fluoride, dissolved (mg/L)	18	0.1– 1.5	0.6– 0.6	0.6(19.0)
Dissolved solids, calculated (mg/L)	18	254–2670	2670– 2670	2670(19.0)
Sediment, total suspended (mg/L)	34	0.2– 741	5.0– 23.5	5.8(19.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	16	0.01– 0.20	-----	0.03(9.0)
Nitrogen, total ammonia (mg/L as N)	18	0.01– 0.11	0.01– 0.01	0.01(19.0)
Phosphorus, total (mg/L as P)	26	0.010– 0.49	0.012– 0.054	0.012(16.8)
Phosphorus, total ortho (mg/L as P)	28	0.001– 0.31	0.001– 0.018	0.001(19.0)
Iron, total recoverable (mg/L)	15	0.04– 0.75	-----	0.17(2.7)
Manganese, total recoverable (mg/L)	12	0.020– 0.37	-----	0.050(2.7)

### Ecological summary:

Prefers cool, very hard waters; fine to medium gravels (0.2- to 3-cm diameter); and middle elevations (3,000 to 3,500 ft). Appears to be somewhat sensitive to suspended sediment and turbidity and relatively indifferent to stream size and total salt content within the study area. Epiphytic on *Cladophora*. Late summer and fall (September) dominant.

### Distribution summary:

Widespread. Prefers the Tongue River drainage and Mizpah Creek.



ECOTYPE: *FRAGILARIA CAPUCINA* DESM.

Biotype(s):

- F. capucina* Desm. var. *capucina*
- F. capucina* var. *acuta* Grun.
- F. capucina* var. *lanceolata* Grun.
- \**F. capucina* var. *mesolepta* Rabh.

Reference:

Patrick and Reimer, 1966 (p. 119; pl. 3, fig. 6)

Herbarium slide number:

1-2-19

Mean percent relative abundance:

0.2

Percent occurrence:

7.6

Abundance-occurrence index:

1.2

Preferred percent occurrence:

0.5

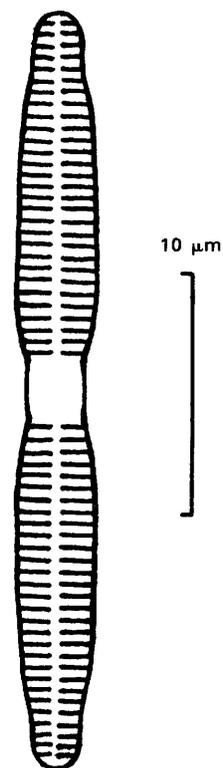
Maximum percent relative abundance:

19.1

Station number: 12

Date: October 18, 1979

Type of collection: E



Description:

Striae, 19-20 in 10  $\mu\text{m}$ . Length, 31.6  $\mu\text{m}$ . Width, 3.7  $\mu\text{m}$ . A medium *Fragilaria* that forms several-celled colonies, which frequently survive the acid-cleaning process intact. Distinguished from other common *Fragilaria* species reported here by the condition that the valves of the two most common forms are either linear (nominate variety) or constricted in the middle (variety *mesolepta*), and not lanceolate or centrally inflated.

Water-quality profile:

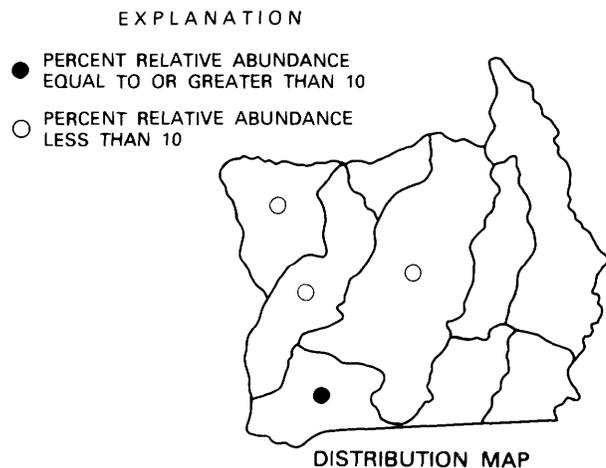
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	22	270- 4890	270- 1590	1590(19.1)
pH (units)-----	22	7.62- 8.45	7.82- 8.03	7.82(19.1)
Temperature ( $^{\circ}\text{C}$ ) -----	22	2.5- 24.5	11.9- 19.5	11.9(19.1)
Turbidity (NTU) -----	22	0.8- 42	0.8- 42	0.8(19.1)
Oxygen, dissolved (mg/L) -----	18	7.45- 13.1	8.58- 8.80	8.80(19.1)
Biochemical oxygen demand (mg/L)-----	7	1.4- 3.0	2.2- 2.2	2.2(19.1)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	13	124- 1100	124- 124	124(12.5)
Calcium, dissolved (mg/L)-----	13	27.4- 116	27.4- 27.4	27.4(12.5)
Magnesium, dissolved (mg/L) -----	13	13.5- 206	13.5- 13.5	13.5(12.5)
Sodium, dissolved (mg/L)-----	15	9.1- 569	9.1- 9.1	9.1(12.5)
Bicarbonate (mg/L) -----	15	111- 816	111- 111	111(12.5)
Carbonate (mg/L)-----	3	1.0- 5.0	-----	1.0(0.8)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	15	91- 669	91- 91	91(12.5)
Sulfate, dissolved (mg/L)-----	15	34- 1490	34- 34	34(12.5)
Chloride, dissolved (mg/L)-----	15	1.3- 30.3	1.3- 1.3	1.3(12.5)
Fluoride, dissolved (mg/L)-----	15	0.1- 1.2	0.1- 0.1	0.1(12.5)
Dissolved solids, calculated (mg/L)-----	13	196- 3210	196- 196	196(12.5)
Sediment, total suspended (mg/L)-----	21	0.2- 135	0.7- 42.5	0.7(19.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	11	0.01- 0.37	0.16- 0.16	0.16(12.5)
Nitrogen, total ammonia (mg/L as N)-----	14	0.01- 0.57	0.05- 0.05	0.05(12.5)
Phosphorus, total (mg/L as P) -----	16	0.010- 0.11	0.11- 0.11	0.11(12.5)
Phosphorus, total ortho (mg/L as P) -----	17	0.001-0.047	0.031-0.031	0.031(12.5)
Iron, total recoverable (mg/L)-----	10	0.02- 0.76	0.76- 0.76	0.76(12.5)
Manganese, total recoverable (mg/L) -----	9	0.005-0.085	0.080-0.080	0.080(12.5)

Ecological summary:

Prefers cool, fresh to slightly brackish, and hard calcium magnesium bicarbonate waters; relatively large concentrations of inorganic nitrogen and total phosphorus; and larger streams (greater than 100 ft<sup>3</sup>/s) at middle elevations (3,000 to 4,000 ft). Substrate indifferent (tychoplanktonic?). Sensitive to large concentrations of suspended sediment and to turbidity. Early summer (June and July) and early fall (October) dominant.

Distribution summary:

Conspicuously absent from the Powder River drainage. Best population development in the Upper Tongue-Hanging Woman hydrologic unit.



ECOTYPE: *FRAGILARIA CONSTRUENS* (EHR.) GRUN.

Biotype(s):

- \**F. construens* (Ehr.) Grun. var. *construens*
- F. construens* var. *pumila* Grun.
- F. construens* var. *venter* (Ehr.) Grun.

Reference:

Patrick and Reimer, 1966 (p. 125; pl. 4, fig. 4)

Herbarium slide number:

1-2-20

Mean percent relative abundance:

0.2

Percent occurrence:

15.9

Abundance-occurrence index:

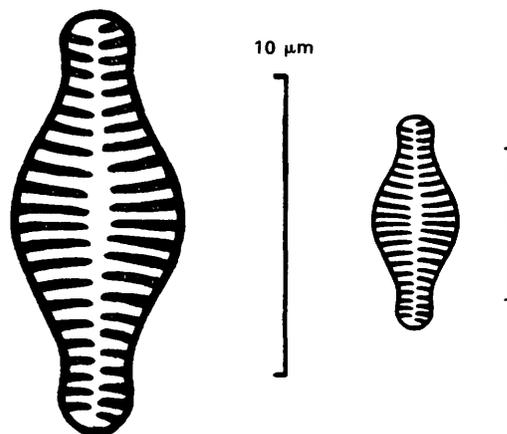
2.6

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

10.5



Station number: 26

Date: November 6, 1979

Type of collection: E

Description:

Striae, 16-18 in 10  $\mu\text{m}$ . Length, 14.0  $\mu\text{m}$ . Width, 5.9  $\mu\text{m}$ . A small, highly variable species of *Fragilaria*. Patrick (Patrick and Reimer, 1966) speculates that the various varieties are really one continuous series and not distinct taxa. Distinguished from *F. leptostauron* (Ehr.) Hust. and varieties by the much finer striae and from the other common species reported here by the smaller size and more lanceolate rather than linear shape.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	44	239-4350	1020- 1020	1020(10.5)
pH (units)	44	7.70- 8.72	8.40- 8.40	8.40(10.5)
Temperature ( $^{\circ}\text{C}$ )	44	1.0- 28.2	3.5- 3.5	3.5(10.5)
Turbidity (NTU)	43	0.9- 435	1.7- 1.7	1.7(10.5)
Oxygen, dissolved (mg/L)	30	6.15- 13.1	13.1- 13.1	13.1(10.5)
Biochemical oxygen demand (mg/L)	9	1.2- 3.5	3.0- 3.0	3.0(10.5)
Hardness, total (mg/L $\text{CaCO}_3$ )	23	145-1430	-----	966(3.4)
Calcium, dissolved (mg/L)	23	33.2- 179	-----	122(3.4)
Magnesium, dissolved (mg/L)	23	15.1- 242	-----	160(3.4)
Sodium, dissolved (mg/L)	25	9.5- 662	55.0- 55.0	55.0(10.5)
Bicarbonate (mg/L)	27	148- 764	561- 561	561(10.5)
Carbonate (mg/L)	5	0.5- 7.2	-----	0.5(2.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	27	124- 627	460- 460	460(10.5)
Sulfate, dissolved (mg/L)	25	41-2390	158- 158	158(10.5)
Chloride, dissolved (mg/L)	25	1.6- 126	4.2- 4.2	4.2(10.5)
Fluoride, dissolved (mg/L)	23	0.1- 12	0.9- 0.9	0.9(10.5)
Dissolved solids, calculated (mg/L)	23	254-4020	-----	2690(3.4)
Sediment, total suspended (mg/L)	41	0.9- 893	1.8- 1.8	1.8(10.5)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	17	0.01- 0.37	0.15- 0.15	0.15(10.5)
Nitrogen, total ammonia (mg/L as N)	23	0.01- 0.57	-----	0.02(3.4)
Phosphorus, total (mg/L as P)	29	0.010- 0.60	0.020-0.020	0.020(10.5)
Phosphorus, total ortho (mg/L as P)	31	0.001- 0.38	0.012-0.012	0.012(10.5)
Iron, total recoverable (mg/L)	9	0.04- 0.29	0.09- 0.09	0.09(10.5)
Manganese, total recoverable (mg/L)	7	0.010- 0.10	-----	0.10(2.7)

Ecological summary:

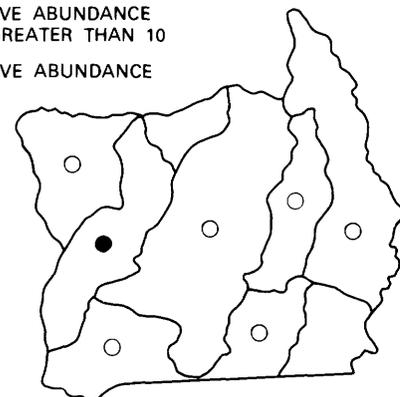
Prefers cold, calcium magnesium bicarbonate waters; small streams (0.1 to 10  $\text{ft}^3/\text{s}$ ) at all but the very highest elevations (less than 4,000 ft); and fine gravel or larger (greater than 0.2-cm diameter). Sensitive to large amounts of suspended sediment and turbidity. Spring (May and June) and fall (September to November) dominant.

Distribution summary:

Widespread. Best population development in Lame Deer Creek near Lame Deer (station 26).

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *FRAGILARIA CROTONENSIS* KITTON

Biotype(s):

*F. crotonensis* Kitton var. *crotonensis*

Reference:

Patrick and Reimer, 1966 (p. 121; pl. 3,  
figs. 11-12)

Herbarium slide number:

1-2-4

Mean percent relative abundance:

0.6

Percent occurrence:

21.1

Abundance-occurrence index:

13.4

Preferred percent occurrence:

0.8

Maximum percent relative abundance:

83.3

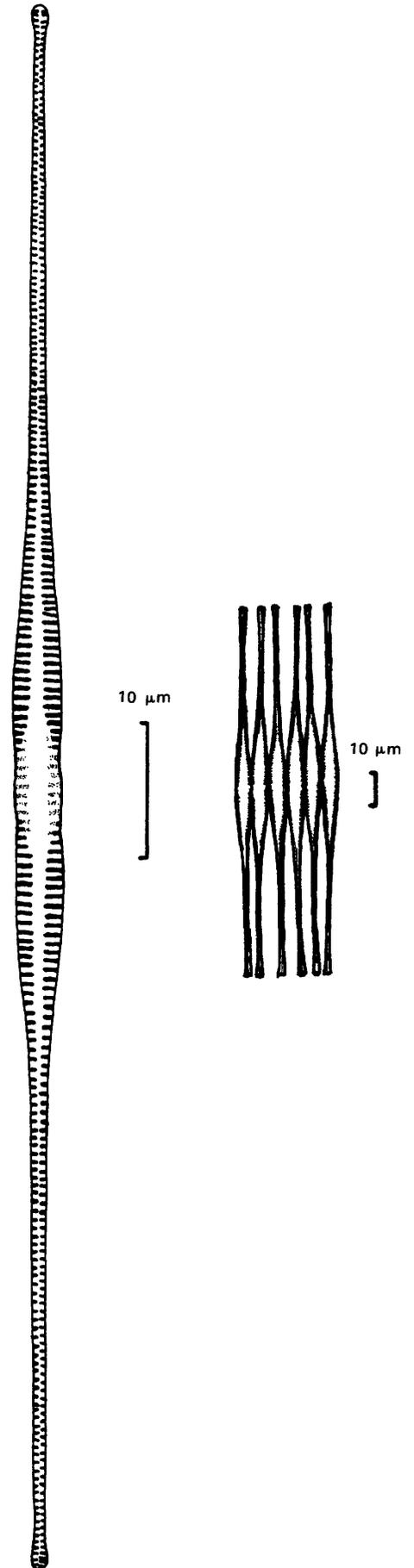
Station number: 51

Date: undated

Type of collection: A

Description:

Striae, 16-19 in 10  $\mu\text{m}$ . Length, 113.0  $\mu\text{m}$ .  
Width, 3.5  $\mu\text{m}$ . A very long, slender species of  
*Fragilaria*. Distinguished by the formation of  
filaments in which the frustules are attached  
only in the middle part of the valve (see drawing).



Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	49	333–6100		480(7.2)
pH (units)	48	7.60– 8.60		7.91(7.2)
Temperature ( $^{\circ}\text{C}$ )	47	2.0– 30.5		18.8(7.2)
Turbidity (NTU)	44	0.8– 376		2.2(6.8)
Oxygen, dissolved (mg/L)	37	6.00– 13.8		12.8(5.1)
Biochemical oxygen demand (mg/L)	16	0.7– 4.2		3.3(4.5)
Hardness, total (mg/L $\text{CaCO}_3$ )	34	123–2020		226(7.2)
Calcium, dissolved (mg/L)	34	16.0– 238		42.8(7.2)
Magnesium, dissolved (mg/L)	34	20.0– 346		28.8(7.2)
Sodium, dissolved (mg/L)	35	11.5– 960		15.8(7.2)
Bicarbonate (mg/L)	36	15– 776		281(7.2)
Carbonate (mg/L)	8	4.8– 22.0		4.8(4.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	36	13– 636		230(7.2)
Sulfate, dissolved (mg/L)	35	17–3350		17(7.2)
Chloride, dissolved (mg/L)	35	1.8– 126		1.8(7.2)
Fluoride, dissolved (mg/L)	34	0.2– 1.3		1.3(7.2)
Dissolved solids, calculated (mg/L)	34	184–5560		389(7.2)
Sediment, total suspended (mg/L)	44	0.9– 741		3.5(6.8)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	23	0.01– 0.71		0.06(7.2)
Nitrogen, total ammonia (mg/L as N)	22	0.01– 0.11		0.03(7.2)
Phosphorus, total (mg/L as P)	36	0.010– 0.49		0.030(7.2)
Phosphorus, total ortho (mg/L as P)	35	0.002– 0.31		0.016(7.2)
Iron, total recoverable (mg/L)	28	0.04– 1.1		0.10(7.2)
Manganese, total recoverable (mg/L)	26	0.019– 0.23		0.045(7.2)

Ecological summary:

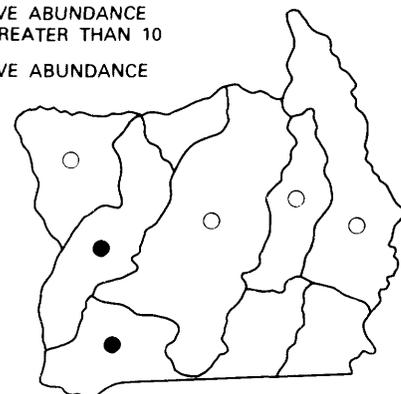
Prefers fresh, calcium magnesium bicarbonate waters; and large streams (greater than 100 ft<sup>3</sup>/s) at middle elevations (3,000 to 3,500 ft). Planktonic. Sensitive to large concentrations of suspended sediment and to turbidity. Summer and fall (August to October) dominant.

Distribution summary:

Widespread. Best population development in standing waters in the Rosebud Creek and upstream Tongue River drainages. Incidental in streams downstream from impoundments.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *FRAGILARIA VAUCHERIAE* (KUTZ.) PETERS.

Biotype(s):

*F. vaucheriae* (Kutz.) Peters. var. *vaucheriae*

Reference:

Patrick and Reimer, 1966 (p. 120; pl. 3,  
figs. 14-15)

Herbarium slide number:

1-3-1

Mean percent relative abundance:

1.4

Percent occurrence:

52.2

Abundance-occurrence index:

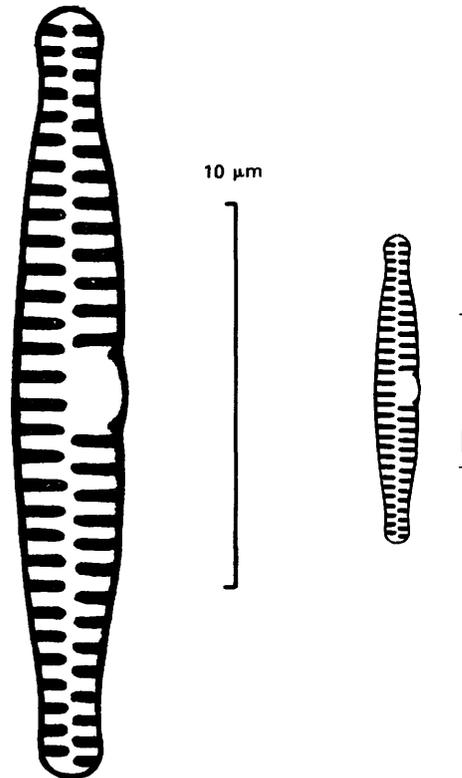
74.4

Preferred percent occurrence:

4.3

Maximum percent relative abundance:

45.1



Station number: 50

Date: October 30, 1979

Type of collection: E

Description:

Striae, 15-16 in 10  $\mu\text{m}$ . Length, 20.0  $\mu\text{m}$ . Width, 3.1  $\mu\text{m}$ . A medium *Fragilaria*, easily distinguished from other species by its asymmetrical, somewhat swollen central area.

Water-quality profile:

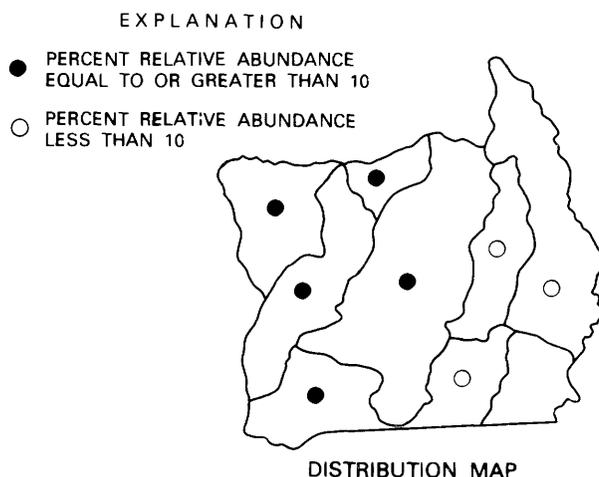
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	148	270-5080	938- 2800	1000(45.1)
pH (units) -----	148	7.50- 8.80	8.02- 8.49	8.38(45.1)
Temperature ( $^{\circ}\text{C}$ ) -----	147	1.0- 30.5	2.0- 16.1	10.00(45.1)
Turbidity (NTU) -----	143	0.5- 435	1.7- 94	1.7(45.1)
Oxygen, dissolved (mg/L) -----	109	5.40- 15.0	10.00- 13.8	13.8(36.6)
Biochemical oxygen demand (mg/L) -----	45	0.5- 8.3	1.7- 3.0	1.8(19.5)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	85	123-2400	424- 635	468(36.6)
Calcium, dissolved (mg/L) -----	85	16.0- 187	70.7- 125	83.2(36.6)
Magnesium, dissolved (mg/L)-----	85	13.5- 467	60.0- 81.0	63.0(36.6)
Sodium, dissolved (mg/L) -----	94	9.1- 662	56.0- 480	64.0(36.6)
Bicarbonate (mg/L)-----	100	15- 776	257- 608	301(45.1)
Carbonate (mg/L) -----	18	0.5- 38.4	-----	38.4(8.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	100	13- 636	211- 498	247(45.1)
Sulfate, dissolved (mg/L) -----	94	17-3150	308- 1290	320(36.6)
Chloride, dissolved (mg/L) -----	94	0.4- 174	4.8- 31.1	5.2(36.6)
Fluoride, dissolved (mg/L) -----	90	0.1- 1.5	0.3- 0.6	0.3(36.6)
Dissolved solids, calculated (mg/L) -----	85	184-4650	757- 2370	841(36.6)
Sediment, total suspended (mg/L) -----	134	0.2- 893	1.1- 310	5.7(45.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	76	0.01- 0.80	0.08- 0.62	0.08(45.1)
Nitrogen, total ammonia (mg/L as N) -----	87	0.01- 0.30	0.01- 0.05	0.01(19.5)
Phosphorus, total (mg/L as P)-----	103	0.010- 0.60	0.010- 0.25	0.020(36.6)
Phosphorus, total ortho (mg/L as P)-----	103	0.001- 0.38	0.002- 0.15	0.002(36.6)
Iron, total recoverable (mg/L)-----	60	0.02- 2.1	0.08- 0.32	0.21(19.5)
Manganese, total recoverable (mg/L)-----	49	0.005- 0.39	0.070-0.090	0.090(19.5)

Ecological summary:

Prefers cool, fresh to slightly brackish, well-oxygenated waters; fine gravels or larger (greater than 0.2-cm diameter) and larger streams (greater than 1 ft<sup>3</sup>/s) at lower elevations (less than 3,500 ft). Tolerates some suspended sediment and turbidity. Tychoplanktonic. Spring (February to March) and fall (October to November) dominant; winter(?).

Distribution summary:

Widespread. Best population development in western part of the study area.



ECOTYPE: *FRAGILARIA* SPECIES X

Biotype(s):

*F.* sp. X var. X

Reference:

None

Herbarium slide number:

1-2-18

Mean percent relative abundance:

0.1

Percent occurrence:

1.4

Abundance-occurrence index:

0.1

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

10.7

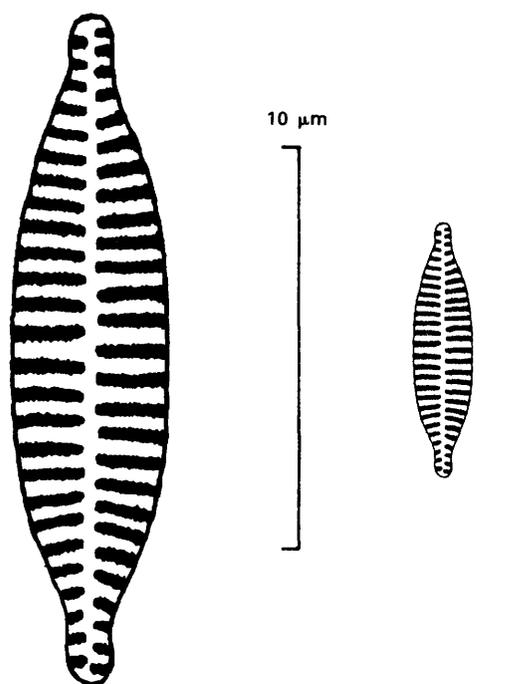
Station number: 35

Date: October 28, 1979

Type of collection: F

Description:

Striae, 15-17 in 10  $\mu\text{m}$ . Length, 17.0  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . A small, highly variable species of *Fragilaria* with narrow, subcapitate ends and offset striae. A unilateral central area, occurring almost to the valve margin, may be present on one or both valves or be entirely absent. Sometimes "ghost striae" are present in the central area. It is distinguished from *F. vaucheriae* and varieties principally in that the central area, when present, is not swollen and does not extend to the valve margin. It is very similar to *F. construens* var. *javanica* Hust., except in its frequent formation of a central area. A search through the Iconograph Reference File, the Diatom Herbarium, and pertinent literature at the Academy of Natural Sciences of Philadelphia failed to reveal the identity of this diatom. It is therefore assumed to be new to science.



Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	2	938- 1500	1500- 1500	1500(10.7)
pH (units) -----	2	8.42- 8.49	8.42- 8.42	8.42(10.7)
Temperature ( $^{\circ}\text{C}$ ) -----	2	10.5- 12.0	10.5- 10.5	10.5(10.7)
Turbidity (NTU) -----	2	3.6- 9.8	9.8- 9.8	9.8(10.7)
Oxygen, dissolved (mg/L) -----	0	-----	-----	-----
Biochemical oxygen demand (mg/L) -----	0	-----	-----	-----
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	0	-----	-----	-----
Calcium, dissolved (mg/L) -----	0	-----	-----	-----
Magnesium, dissolved (mg/L) -----	0	-----	-----	-----
Sodium, dissolved (mg/L) -----	0	-----	-----	-----
Bicarbonate (mg/L) -----	2	295- 514	514- 514	514(10.7)
Carbonate (mg/L) -----	2	0.0- 0.0	0.0- 0.0	0.0(10.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	2	242- 421	421- 421	421(10.7)
Sulfate, dissolved (mg/L) -----	0	-----	-----	-----
Chloride, dissolved (mg/L) -----	0	-----	-----	-----
Fluoride, dissolved (mg/L) -----	0	-----	-----	-----
Dissolved solids, calculated (mg/L) -----	0	-----	-----	-----
Sediment, total suspended (mg/L) -----	2	5.4- 18.8	18.8- 18.8	18.8(10.7)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	2	0.00- 0.00	0.00- 0.00	0.00(10.7)
Nitrogen, total ammonia (mg/L as N) -----	2	0.00- 0.02	0.02- 0.02	0.02(10.7)
Phosphorus, total (mg/L as P) -----	2	0.000-0.020	0.020-0.020	0.020(10.7)
Phosphorus, total ortho (mg/L as P) -----	2	0.005-0.008	0.008-0.008	0.008(10.7)
Iron, total recoverable (mg/L) -----	0	-----	-----	-----
Manganese, total recoverable (mg/L) -----	0	-----	-----	-----

Ecological summary:

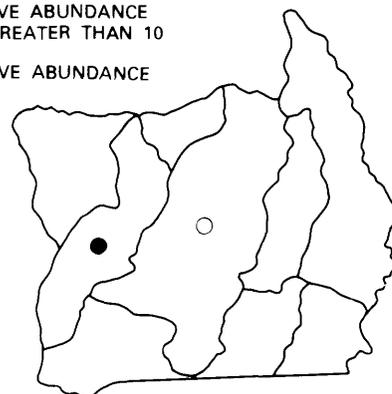
Prefers cool, slightly brackish waters of pH greater than 8.00 (alkalibiontic), and larger streams (10 to 100  $\text{ft}^3/\text{s}$ ). Tolerates some suspended sediment and turbidity. Fall (October) dominant. Limited environmental information.

Distribution summary:

Found only in Rosebud Creek near Colstrip (station 35) and the Tongue River near Brandenburg (station 47). Dominant in Rosebud Creek.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *GOMPHONEMA ANGUSTATUM* (KUTZ.) RABH.

Biotype(s):

- \**G. angustatum* (Kutz.) Rabh. var. *angustatum*
- G. angustatum* var. *citera* (Hohn and Hellerm.)  
Patr.
- G. angustatum* var. *intermedia* Grun.
- G. angustatum* var. *obtusatum* (Kutz.) Grun.
- G. angustatum* var. *sarcophagus* (Greg.) Grun.

Reference:

Patrick and Reimer, 1975 (p. 125; pl. 17,  
figs. 17-19)

Herbarium slide number:

1-3-2

Mean percent relative abundance:

0.4

Percent occurrence:

34.3

Abundance-occurrence index:

14.7

Preferred percent occurrence:

0.8

Maximum percent relative abundance:

18.0

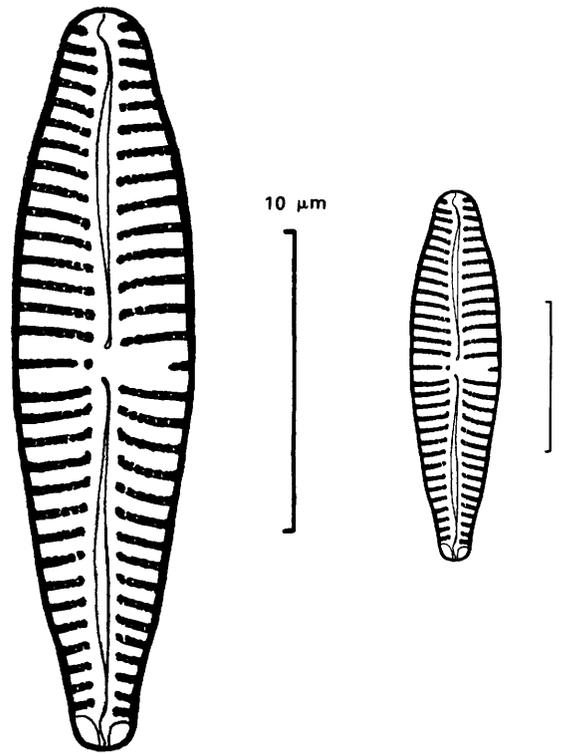
Station number: 37

Date: May 13, 1979

Type of collection: E

Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Length, 24.8  $\mu\text{m}$ . Width, 6.0  $\mu\text{m}$ . Distinguished by the somewhat protracted, often rostrate apices and by a single isolated punctum in the central area. Patrick (Patrick and Reimer, 1975) speculates that further study may indicate that the varieties of this species intergrade with the nominate variety and are not distinct.



Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	107	239- 6100	1210- 6100	3090(18.0)
pH (units) -----	107	7.50- 8.73	8.00- 8.50	8.12(18.0)
Temperature ( $^{\circ}\text{C}$ ) -----	108	1.7- 30.2	13.3- 18.3	13.3(18.0)
Turbidity (NTU) -----	107	0.7-11600	14- 46	24(18.0)
Oxygen, dissolved (mg/L) -----	77	5.22- 19.0	9.30- 10.2	10.2(18.0)
Biochemical oxygen demand (mg/L) -----	27	0.8- 7.8	2.6- 4.2	2.6(18.0)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	73	92- 2400	1020- 2020	1020(18.0)
Calcium, dissolved (mg/L) -----	73	27.4- 238	124- 238	124(18.0)
Magnesium, dissolved (mg/L)-----	73	5.0- 467	173- 346	173(18.0)
Sodium, dissolved (mg/L) -----	76	9.1- 1230	410- 960	410(18.0)
Bicarbonate (mg/L)-----	77	111- 816	587- 647	587(18.0)
Carbonate (mg/L) -----	17	1.0- 22.0	-----	5.0(6.1)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	77	91- 669	481- 530	481(18.0)
Sulfate, dissolved (mg/L) -----	76	34- 3350	1370- 3350	1370(18.0)
Chloride, dissolved (mg/L) -----	76	0.4- 126	14.0- 15.2	14.0(18.0)
Fluoride, dissolved (mg/L) -----	71	0.1- 1.7	0.3- 0.6	0.3(18.0)
Dissolved solids, calculated (mg/L) -----	73	196- 5560	2670- 5560	2670(18.0)
Sediment, total suspended (mg/L) -----	97	0.2-22600	24.2- 64.2	64.2(18.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	58	0.01- 0.71	0.01- 0.01	0.01(18.0)
Nitrogen, total ammonia (mg/L as N) -----	72	0.01- 0.22	0.02- 0.02	0.02(18.0)
Phosphorus, total (mg/L as P)-----	80	0.010- 3.7	0.050-0.090	0.050(18.0)
Phosphorus, total ortho (mg/L as P)-----	82	0.001- 2.5	0.009-0.041	0.021(18.0)
Iron, total recoverable (mg/L)-----	47	0.02- 2.1	0.51- 0.79	0.79(18.0)
Manganese, total recoverable (mg/L)-----	45	0.005- 0.37	0.18- 0.20	0.18(18.0)

Ecological summary:

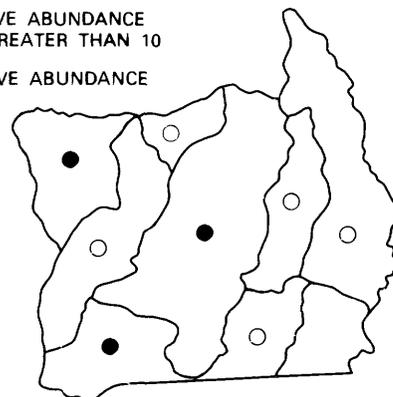
Prefers cool, brackish, extremely hard, sodium sulfate waters; fine gravels or larger (greater than 0.2-cm diameter); and all but the very largest streams (less than 100 ft<sup>3</sup>/s) at lower and middle elevations (less than 4,000 ft). Somewhat sensitive to suspended sediment and turbidity. Spring (May) and fall (October) dominant.

Distribution summary:

Widespread. Best population development in Sarpy Creek and tributaries to the Tongue River.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *GOMPHONEMA OLIVACEUM* (LYNGB.) KUTZ.

Biotype(s):

\**G. olivaceum* (Lyngb.) Kutz. var. *olivaceum*  
*G. olivaceum* var. *calcareum* (Cl.) Cl.

Reference:

Patrick and Reimer, 1975 (p. 139; pl. 18,  
figs. 13-14)

Herbarium slide number:

1-3-3

Mean percent relative abundance:

2.1

Percent occurrence:

58.1

Abundance-occurrence index:

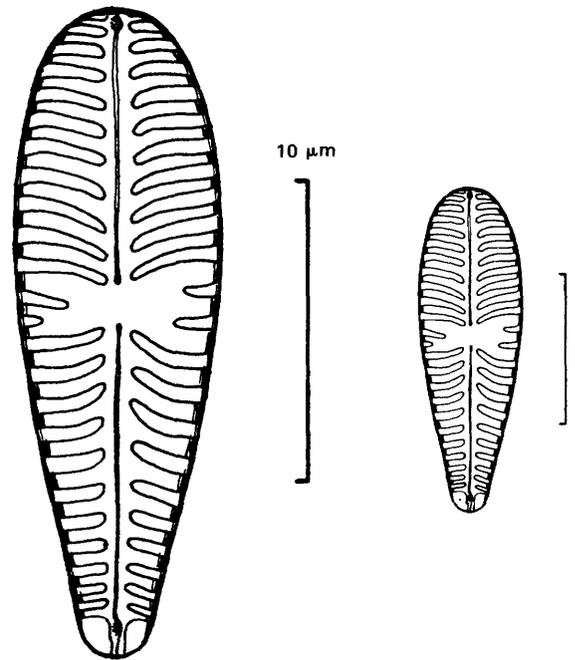
121.5

Preferred percent occurrence:

6.2

Maximum percent relative abundance:

49.7



Station number: 7

Date: May 20, 1979

Type of collection: E

Description:

Striae, 11-13 in 10  $\mu\text{m}$ . Length, 21.8  $\mu\text{m}$ . Width, 7.0  $\mu\text{m}$ . The only common *Gomphonema* in the study area without an isolated punctum in the central area.

Water-quality profile:

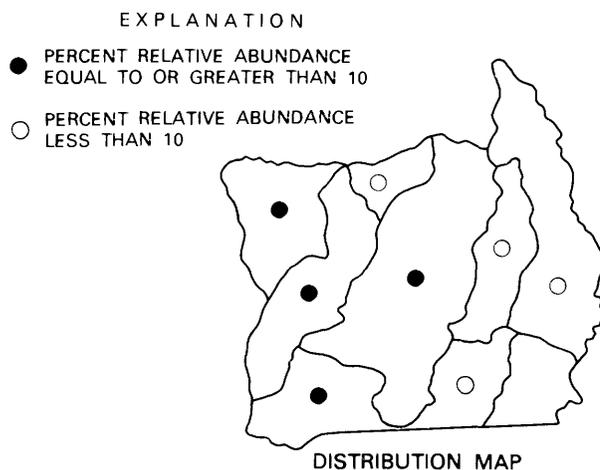
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	166	239-11000	292- 3520	818(49.7)
pH (units) -----	166	7.50- 8.80	7.90- 8.40	8.28(49.7)
Temperature ( $^{\circ}\text{C}$ ) -----	166	1.7- 27.3	3.5- 21.0	12.9(49.7)
Turbidity (NTU) -----	161	0.5- 4200	1.7- 24	17(49.7)
Oxygen, dissolved (mg/L) -----	127	4.52- 15.3	7.60- 13.8	9.33(49.7)
Biochemical oxygen demand (mg/L) -----	53	0.5- 8.9	1.0- 3.0	1.4(49.7)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	105	124- 3490	145- 1120	456(49.7)
Calcium, dissolved (mg/L) -----	105	27.4- 328	33.2- 151	81.3(49.7)
Magnesium, dissolved (mg/L)-----	105	13.5- 645	15.1- 183	61.0(49.7)
Sodium, dissolved (mg/L) -----	111	9.1- 1950	9.5- 502	17.2(49.7)
Bicarbonate (mg/L)-----	116	15- 764	151- 730	402(49.7)
Carbonate (mg/L) -----	24	1.0- 38.4	-----	7.0(6.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	116	13- 627	124- 598	330(49.7)
Sulfate, dissolved (mg/L) -----	111	34- 6900	43- 1690	156(49.7)
Chloride, dissolved (mg/L) -----	111	0.4- 88.9	1.6- 14.0	2.5(49.7)
Fluoride, dissolved (mg/L) -----	108	0.1- 1.7	0.1- 0.9	0.5(49.7)
Dissolved solids, calculated (mg/L) -----	105	184-10400	254- 3030	721(49.7)
Sediment, total suspended (mg/L) -----	154	0.2- 8260	1.1- 64.2	51.2(49.7)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	91	0.01- 0.80	0.01- 0.66	0.07(44.1)
Nitrogen, total ammonia (mg/L as N) -----	95	0.01- 0.22	0.01- 0.22	0.01(44.1)
Phosphorus, total (mg/L as P)-----	118	0.010- 3.7	0.020-0.099	0.060(49.7)
Phosphorus, total ortho (mg/L as P)-----	123	0.001- 2.5	0.002-0.021	0.017(49.7)
Iron, total recoverable (mg/L)-----	71	0.02- 2.1	0.09- 0.83	0.31(38.0)
Manganese, total recoverable (mg/L)-----	64	0.005- 0.41	0.055- 0.18	0.055(38.0)

Ecological summary:

Prefers cool, fresh to slightly brackish, calcium-magnesium bicarbonate waters; fine gravel or larger (greater than 0.2-cm diameter); and medium to large streams (greater than 1  $\text{ft}^3/\text{s}$ ) at the middle elevations (2,500 to 4,000 ft). Tolerates some suspended sediment and turbidity. Fall to winter(?) to spring (October-?-June) dominant.

Distribution summary:

Widespread. Best population development in the western part of the study area.



ECOTYPE: *GOMPHONEMA TENELLUM* KUTZ.

Biotype(s):

*G. tenellum* Kutz. var. *tenellum*

Reference:

Patrick and Reimer, 1975 (p. 124; pl. 17,  
figs. 16a-b)

Herbarium slide number:

1-3-4

Mean percent relative abundance:

0.5

Percent occurrence:

20.8

Abundance-occurrence index:

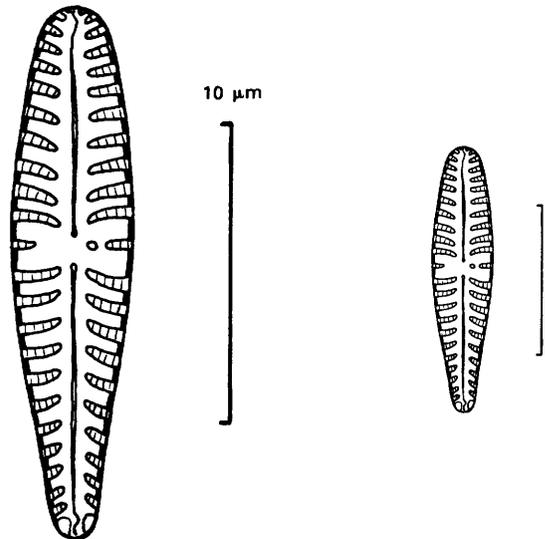
10.6

Preferred percent occurrence:

1.1

Maximum percent relative abundance:

17.0



Station number: 9

Date: August 27, 1978

Type of collection: C

Description:

Striae, 11-13 in 10  $\mu\text{m}$ . Length, 17.6  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . Distinguished from the other two common species of *Gomphonema* from the study area by having an isolated punctum in the central area and ends that are not protracted.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	71	292-4350	610- 882	610(17.0)
pH (units)	71	7.70- 8.80	8.00- 8.37	8.20(17.0)
Temperature ( $^{\circ}\text{C}$ )	72	2.0- 30.5	18.1- 20.0	18.1(17.0)
Turbidity (NTU)	71	0.5- 190	1.4- 12	2.2(17.0)
Oxygen, dissolved (mg/L)	49	5.22- 13.2	7.70- 9.10	7.70(14.2)
Biochemical oxygen demand (mg/L)	15	1.0- 3.5	1.0- 2.2	2.2(14.2)
Hardness, total (mg/L $\text{CaCO}_3$ )	44	123-1430	288- 375	288(17.0)
Calcium, dissolved (mg/L)	44	16.0- 183	58.4- 69.6	58.4(17.0)
Magnesium, dissolved (mg/L)	44	15.1- 242	34.5- 48.9	34.5(17.0)
Sodium, dissolved (mg/L)	46	9.5- 662	12.8- 31.1	26.9(17.0)
Bicarbonate (mg/L)	47	15- 776	222- 392	222(17.0)
Carbonate (mg/L)	18	0.5- 38.4		7.0(6.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	47	13- 636	182- 321	182(17.0)
Sulfate, dissolved (mg/L)	46	43-2390	69- 163	149(17.0)
Chloride, dissolved (mg/L)	46	0.4- 21.4	2.4- 3.4	3.1(17.0)
Fluoride, dissolved (mg/L)	45	0.1- 1.2	0.3- 0.6	0.3(17.0)
Dissolved solids, calculated (mg/L)	44	184-4020	494- 596	494(17.0)
Sediment, total suspended (mg/L)	68	0.8- 413	2.9- 67.4	3.5(17.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	38	0.01- 0.80	0.08- 0.08	0.08(14.2)
Nitrogen, total ammonia (mg/L as N)	41	0.01- 0.05	0.01- 0.02	0.01(17.0)
Phosphorus, total (mg/L as P)	49	0.010- 0.25	0.014-0.064	0.014(17.0)
Phosphorus, total ortho (mg/L as P)	51	0.001- 0.15	0.006-0.023	0.006(17.0)
Iron, total recoverable (mg/L)	38	0.02- 1.4	0.59- 0.59	0.59(14.2)
Manganese, total recoverable (mg/L)	35	0.005- 0.15	0.095-0.095	0.095(14.2)

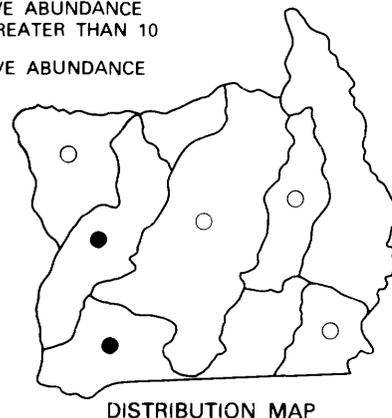
Ecological summary:

Prefers fresh, calcium-magnesium bicarbonate waters; fine to medium gravels (0.2- to 3-cm diameter); and larger streams (greater than 10 ft<sup>3</sup>/s) at middle elevations (3,000 to 4,000 ft). Stenothermal between 18 and 20  $^{\circ}\text{C}$ . Sensitive to large amounts of suspended sediment and turbidity. Summer (July to September) dominant.

Distribution summary:

Found in all areas except the Middle Powder and Lower Powder hydrologic units. Best population development in the upstream Tongue River and Rosebud Creek drainages.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



ECOTYPE: *MELOSIRA VARIANS* C. A. AG.

Biotype(s):

*M. varians* C. A. Ag. var. *variens*

Reference:

Hustedt, 1930b (p. 85; fig. 41)

Herbarium slide number:

1-3-5

Mean percent relative abundance:

0.3

Percent occurrence:

22.7

Abundance-occurrence index:

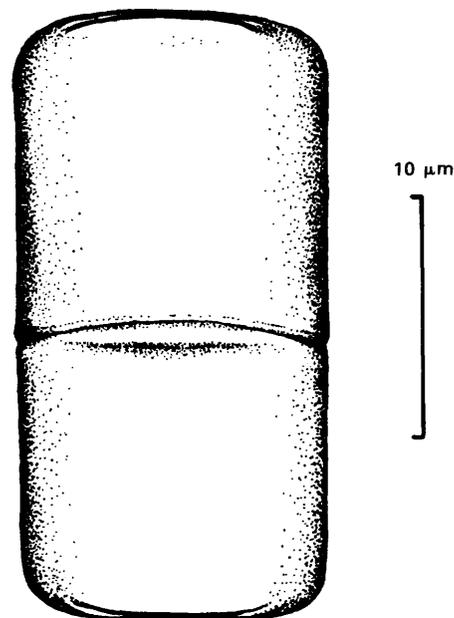
6.2

Preferred percent occurrence:

0.8

Maximum percent relative abundance:

30.4



Station number: 29

Date: September 8, 1978

Type of collection: E

Description:

Diameter, 13.3  $\mu\text{m}$ . Length of frustule (girdle view), 25.3  $\mu\text{m}$ . A large species of *Melosira*, most frequently found in girdle view. Distinguished from other species of this genus by the absence of visibly distinctive ornamentation.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	70	239–4220	333– 1580	1580(30.4)
pH (units)	70	7.50– 8.59	8.02– 8.29	8.08(30.4)
Temperature ( $^{\circ}\text{C}$ )	70	2.8– 25.9	18.2– 20.3	20.3(30.4)
Turbidity (NTU)	66	0.5– 190	0.5– 24	1.7(30.4)
Oxygen, dissolved (mg/L)	51	6.78– 13.7	8.00– 12.2	8.00(14.9)
Biochemical oxygen demand (mg/L)	22	0.5– 3.5	1.4– 1.4	1.4(14.9)
Hardness, total (mg/L $\text{CaCO}_3$ )	41	124–1080	667– 780	780(30.4)
Calcium, dissolved (mg/L)	41	27.4– 134	71.7– 87.2	87.2(30.4)
Magnesium, dissolved (mg/L)	41	13.5– 194	118– 137	137(30.4)
Sodium, dissolved (mg/L)	47	9.1– 385	100– 118	118(30.4)
Bicarbonate (mg/L)	49	111– 754	517– 569	569(30.4)
Carbonate (mg/L)	9	2.0– 24.0	-----	24.0(0.9)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	49	91– 618	424– 467	467(30.4)
Sulfate, dissolved (mg/L)	47	34–1070	436– 498	498(30.4)
Chloride, dissolved (mg/L)	47	1.2– 51.6	4.9– 5.7	4.9(30.4)
Fluoride, dissolved (mg/L)	47	0.1– 1.5	0.7– 0.7	0.7(30.4)
Dissolved solids, calculated (mg/L)	41	196–2300	1250– 1410	1410(30.4)
Sediment, total suspended (mg/L)	68	0.2– 413	0.6– 3.4	3.4(30.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	44	0.01– 0.38	0.02– 0.06	0.06(30.4)
Nitrogen, total ammonia (mg/L as N)	41	0.01– 0.07	0.04– 0.04	0.04(30.4)
Phosphorus, total (mg/L as P)	57	0.010– 0.11	0.030– 0.030	0.030(30.4)
Phosphorus, total ortho (mg/L as P)	57	0.001– 0.12	0.007– 0.015	0.015(30.4)
Iron, total recoverable (mg/L)	41	0.04– 0.76	0.13– 0.18	0.18(30.4)
Manganese, total recoverable (mg/L)	36	0.005– 0.39	0.040– 0.058	0.058(30.4)

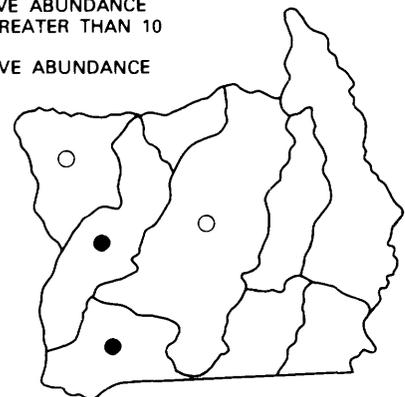
Ecological summary:

Prefers fresh to slightly brackish, magnesium sulfate bicarbonate waters; pH between 8.00 and 8.30; fine sand or larger (greater than 0.05-mm diameter); and larger streams (greater than 1  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 3,500 ft). Stenothermal between 18 and 21  $^{\circ}\text{C}$ . Sensitive to small amounts of suspended sediment and chloride. Summer dominant (June to September).

Distribution summary:

Conspicuously absent from the Powder River drainage. Best population development in Muddy Creek near Busby (station 29) and the upstream part of the Tongue River.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NAVICULA CINCTA* (EHR.) RALFS VAR. *CINCTA*

Biotype(s):

*N. cincta* (Ehr.) Ralfs var. *cincta*

Reference:

Patrick and Reimer, 1966 (p. 516; pl. 49, fig. 8)

Herbarium slide number:

1-3-6

Mean percent relative abundance:

1.9

Percent occurrence:

51.9

Abundance-occurrence index:

100.4

Preferred percent occurrence:

6.2

Maximum percent relative abundance:

43.1

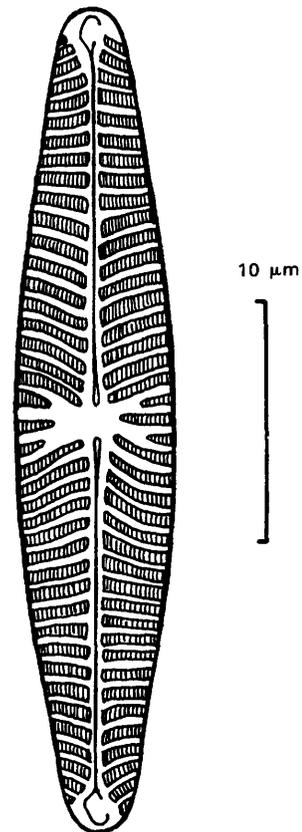
Station number: 5

Date: August 7, 1979

Type of collection: E

Description:

Striae, 10-14 in 10  $\mu\text{m}$ . Length, 30.2  $\mu\text{m}$ . Width, 6.6  $\mu\text{m}$ . Distinguished from similar species of *Navicula* by the characteristic transverse central area. Patrick and Reimer (1966, p. 516) describe the central area as "sometimes formed by the striae at the center of the valve being shorter than the others and more distant from each other; at other times the two central striae reach almost to the central nodule while those on each side are much shorter, thus giving the central area an irregular appearance." In our specimens, the striae at the valve ends are not as dense as stated by Patrick and Reimer ("... to 17 in 10  $\mu\text{m}$  at the ends"). However, our specimens do have the characteristic central area, which sets them apart from *N. heufleri* Grun. and varieties.



Water-quality profile:

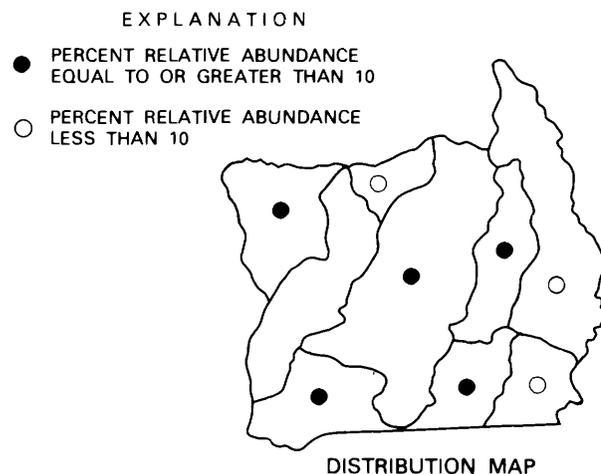
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	165	480-11000	900- 3810	3270(43.1)
pH (units)-----	165	7.41- 8.73	7.82- 8.73	8.46(43.1)
Temperature ( $^{\circ}\text{C}$ ) -----	164	1.3- 30.5	10.5- 30.5	25.9(43.1)
Turbidity (NTU) -----	163	0.7-11600	2.4-11600	26(43.1)
Oxygen, dissolved (mg/L) -----	117	0.80- 19.0	5.40- 12.1	8.48(43.1)
Biochemical oxygen demand (mg/L)-----	39	0.5- 8.3	5.2- 5.2	5.2(26.9)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	93	92- 3490	92- 1250	981(27.8)
Calcium, dissolved (mg/L)-----	93	16.0- 328	16.0- 179	85.6(27.8)
Magnesium, dissolved (mg/L)-----	93	5.0- 645	5.0- 204	186(27.8)
Sodium, dissolved (mg/L)-----	99	15.8- 1950	133- 835	390(27.8)
Bicarbonate (mg/L) -----	103	171- 913	261- 776	630(27.8)
Carbonate (mg/L)-----	21	0.5- 36.0	2.4- 26.0	2.4(27.8)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	103	146- 748	214- 636	521(27.8)
Sulfate, dissolved (mg/L)-----	99	17- 6900	380- 1560	1230(27.8)
Chloride, dissolved (mg/L)-----	99	0.4- 174	2.2- 24.0	10.4(27.8)
Fluoride, dissolved (mg/L)-----	95	0.1- 1.7	0.6- 0.8	0.7(27.8)
Dissolved solids, calculated (mg/L)-----	93	389-10400	992- 3260	2540(27.8)
Sediment, total suspended (mg/L)-----	145	0.4-22600	3.5-22600	46.6(43.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	70	0.01- 0.71	0.02- 0.12	0.02(43.1)
Nitrogen, total ammonia (mg/L as N)-----	100	0.01- 0.57	0.01- 0.08	0.02(43.1)
Phosphorus, total (mg/L as P) -----	113	0.010- 3.7	0.020- 0.25	0.080(43.1)
Phosphorus, total ortho (mg/L as P) -----	111	0.001- 2.5	0.005- 0.22	0.031(43.1)
Iron, total recoverable (mg/L)-----	47	0.04- 2.1	0.34- 2.1	0.46(14.3)
Manganese, total recoverable (mg/L)-----	44	0.005- 0.41	0.054- 0.27	0.095(14.3)

Ecological summary:

Prefers somewhat brackish, moderately hard to extremely hard sodium sulfate waters; fine gravels or larger (greater than 0.2-cm diameter); and lower elevations (less than 3,500 ft). Apparently indifferent to stream size, large concentrations of suspended sediment, and turbidity. Eurythermal between 10 and 31  $^{\circ}\text{C}$ . Summer (June to August) dominant.

Distribution summary:

Found throughout the study area. A dominant in all but the Little Powder and Lower Powder hydrologic units.



ECOTYPE: *NAVICULA CINCTA* VAR. *ROSTRATA* REIM.

Biotype(s):

*N. cincta* var. *rostrata* Reim.

Reference:

Reimer, 1961 (p. 314; pl. 1, fig. 1)

Herbarium slide number:

1-3-7

Mean percent relative abundance:

2.2

Percent occurrence:

76.5

Abundance-occurrence index:

167.6

Preferred percent occurrence:

5.4

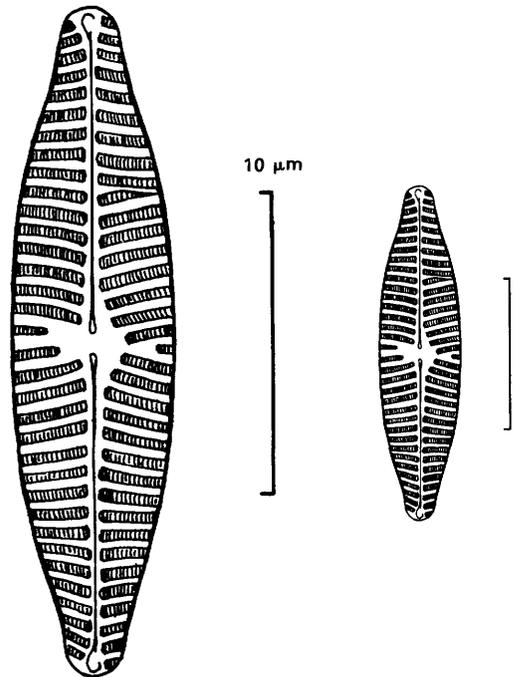
Maximum percent relative abundance:

25.3

Station number: 23

Date: October 28, 1979

Type of collection: E



Description:

Striae, 15-16 in 10  $\mu\text{m}$ . Length, 24.3  $\mu\text{m}$ . Width, 5.5  $\mu\text{m}$ . This variety has rostrate ends, which make it easily distinguishable from the nominate variety in which the ends are attenuate and not set off from the valve body. Other features are very similar to those of the nominate variety, including the typically transverse central area.

Water-quality profile:

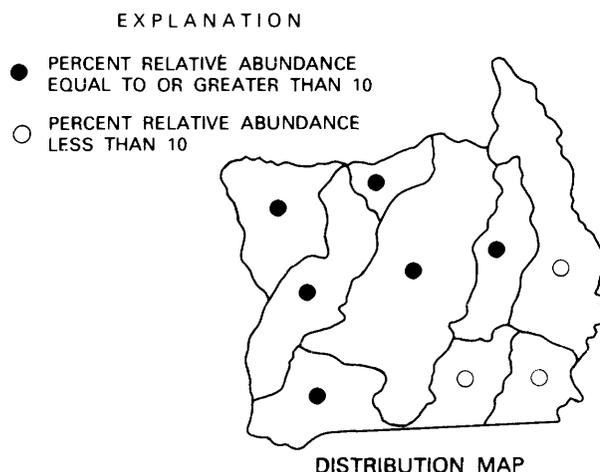
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	243	239-11000	958- 6100	5550(24.4)
pH (units) -----	242	7.50- 8.80	7.70- 8.50	8.12(24.4)
Temperature ( $^{\circ}\text{C}$ ) -----	241	1.0- 30.5	1.3- 26.7	22.0(24.4)
Turbidity (NTU) -----	242	0.5-11600	0.7- 23	5.9(24.4)
Oxygen, dissolved (mg/L) -----	176	3.82- 19.0	4.52- 14.3	11.0(24.4)
Biochemical oxygen demand (mg/L) -----	65	0.8- 8.9	1.5- 3.6	3.5(21.9)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	144	92- 3490	402- 2300	2080(22.3)
Calcium, dissolved (mg/L) -----	144	16.0- 330	54.3- 257	220(22.3)
Magnesium, dissolved (mg/L)-----	144	5.0- 645	55.0- 416	373(22.3)
Sodium, dissolved (mg/L) -----	156	11.5- 1950	66.1- 878	878(22.3)
Bicarbonate (mg/L)-----	162	148- 913	272- 913	272(22.3)
Carbonate (mg/L) -----	33	0.5- 38.4	8.4- 14.0	8.4(22.3)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	162	133- 748	225- 748	237(22.3)
Sulfate, dissolved (mg/L) -----	156	17- 6900	248- 3770	3770(22.3)
Chloride, dissolved (mg/L) -----	156	0.4- 174	4.0- 43.1	33.5(22.3)
Fluoride, dissolved (mg/L) -----	151	0.04- 1.7	0.2- 1.7	0.2(22.3)
Dissolved solids, calculated (mg/L) -----	144	389-10400	781- 5560	5560(22.3)
Sediment, total suspended (mg/L) -----	221	0.2-22600	1.0- 45.6	6.9(22.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	118	0.01- 0.80	0.05- 0.71	0.10(21.9)
Nitrogen, total ammonia (mg/L as N) -----	147	0.01- 0.57	0.01- 0.57	0.03(22.3)
Phosphorus, total (mg/L as P)-----	170	0.010- 3.7	0.010-0.070	0.030(22.3)
Phosphorus, total ortho (mg/L as P)-----	173	0.001- 2.5	0.003-0.047	0.006(22.3)
Iron, total recoverable (mg/L)-----	101	0.02- 1.4	0.08- 0.36	0.08(21.9)
Manganese, total recoverable (mg/L)-----	89	0.005- 0.41	0.025- 0.41	0.41(19.2)

Ecological summary:

Prefers brackish, extremely hard, sodium sulfate waters; fine sand or larger (greater than 0.015-mm diameter); and small streams (less than 10 ft<sup>3</sup>/s) at all elevations in the study area. Sensitive to large concentrations of suspended sediment and turbidity. Eurythermal between 1 and 27°C. Apparently without a seasonal preference. This taxon differs ecologically from the nominate variety in that it prefers somewhat cooler, more brackish, and less turbid water.

Distribution summary:

Found throughout the study area. A dominant in all hydrologic units except those representing the Powder and Little Powder Rivers.



ECOTYPE: *NAVICULA CRYPTOCEPHALA* VAR. *VENETA* (KUTZ.) RABH.

Biotype(s):

*N. cryptocephala* var. *veneta* (Kutz.) Rabh.

Reference:

Patrick and Reimer, 1966 (p. 504; pl. 48, fig. 5)

Herbarium slide number:

1-3-10

Mean percent relative abundance:

1.1

Percent occurrence:

75.4

Abundance-occurrence index:

85.7

Preferred percent occurrence:

0.5

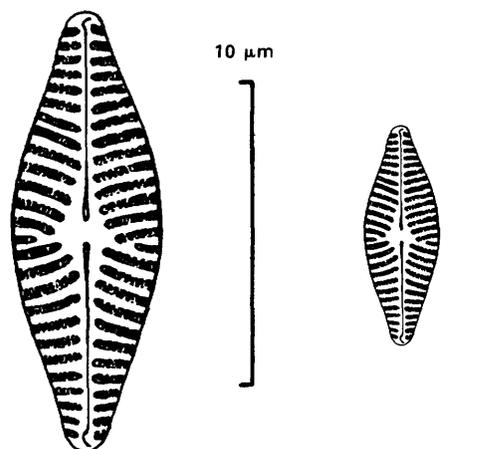
Maximum percent relative abundance:

20.9

Station number: 22

Date: June 10, 1976

Type of collection: F



Description:

Striae, 15-17 in 10  $\mu\text{m}$ . Length, 14.6  $\mu\text{m}$ . Width, 5.0  $\mu\text{m}$ . A small, lanceolate *Navicula* with an irregular and sometimes indistinct central area. Distinguished from *N. radiosa* var. *tenella* by the slightly protracted ends and from *N. cincta* var. *rostrata* by the inconspicuous central area. *N. gregaria* has striae that are more nearly parallel and a central area that is more distinct.

Water-quality profile:

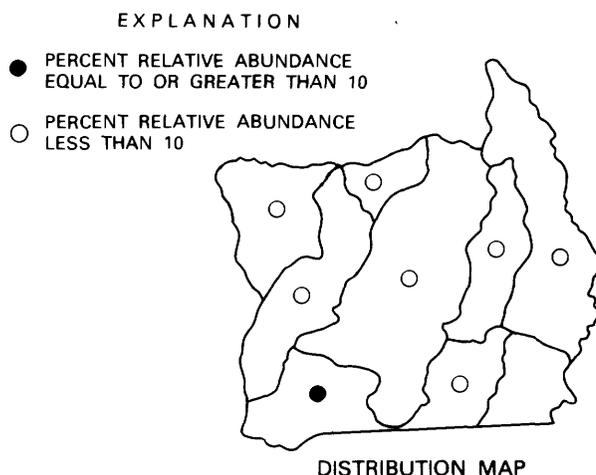
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	224	239–11000		6000(7.2)
pH (units)	224	7.50– 8.73		8.20(7.2)
Temperature ( $^{\circ}\text{C}$ )	226	1.0– 30.5		22.0(7.2)
Turbidity (NTU)	219	0.5–11600		15(7.2)
Oxygen, dissolved (mg/L)	168	0.80– 19.0		12.0(7.0)
Biochemical oxygen demand (mg/L)	63	0.5– 8.3		1.8(5.8)
Hardness, total (mg/L $\text{CaCO}_3$ )	137	92– 3490		1400(7.2)
Calcium, dissolved (mg/L)	137	16.0– 330		190(7.2)
Magnesium, dissolved (mg/L)	137	5.0– 645		226(7.2)
Sodium, dissolved (mg/L)	146	9.1– 1950		1040(7.2)
Bicarbonate (mg/L)	152	45– 816		651(7.2)
Carbonate (mg/L)	34	0.5– 29.0		14.0(3.0)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	152	39– 669		534(7.2)
Sulfate, dissolved (mg/L)	146	34– 6900		3170(7.2)
Chloride, dissolved (mg/L)	146	0.4– 174		23.8(7.2)
Fluoride, dissolved (mg/L)	144	0.04– 1.7		0.04(7.2)
Dissolved solids, calculated (mg/L)	137	196–10400		5300(7.2)
Sediment, total suspended (mg/L)	203	0.2–22600		26.6(7.2)
Nitrogen, total $\text{NO}_2+\text{NO}_3$ (mg/L as N)	107	0.01– 0.71		0.03(7.0)
Nitrogen, total ammonia (mg/L as N)	129	0.01– 0.57		0.01(7.2)
Phosphorus, total (mg/L as P)	152	0.010– 3.7		0.032(7.2)
Phosphorus, total ortho (mg/L as P)	152	0.001– 2.5		0.008(7.2)
Iron, total recoverable (mg/L)	93	0.02– 2.1		0.08(7.0)
Manganese, total recoverable (mg/L)	83	0.010– 0.39		0.030(7.0)

Ecological summary:

There is a limited amount of chemical and physical data associated with populations having a relative abundance of 10 percent or greater. Seems to prefer brackish waters with some carbonate ion and relatively large concentrations of sulfate and sodium; fine sand or larger (greater than 0.05-mm diameter); and middle elevations (2,500 to 4,000 ft). Tolerates small concentrations of chloride, suspended sediment, and turbidity. Seems to be indifferent to stream size and season of the year.

Distribution summary:

Widespread, but rarely found in abundance. Best population development in the upstream Tongue River drainage.



ECOTYPE: *NAVICULA GOERSII* BAHLS

Biotype(s):

*N. goersii* Bahls var. *goersii*

Reference:

Bahls, 1983 (p. 1; fig. 1)

Herbarium slide number:

1-3-17

Mean percent relative abundance:

0.2

Percent occurrence:

22.2

Abundance-occurrence index:

4.6

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

10.5

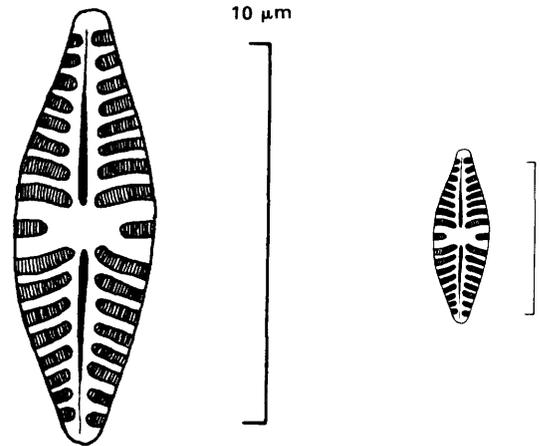
Station number: 21

Date: August 24, 1979

Type of collection: E

Description:

Striae, 14-16 in 10  $\mu\text{m}$ . Length, 11.0  $\mu\text{m}$ . Width, 3.5  $\mu\text{m}$ . This taxon could not be identified using references immediately available to the principal author. After a search through the Iconograph Reference File, the Diatom Herbarium, and pertinent literature at the Academy of Natural Sciences of Philadelphia, it was concluded that this taxon is new to science. It was named and described in a recent paper (Bahls, 1983). *Navicula goersii* is closely related to *N. dulcis* Patr., which was not found in the study area but which has very similar morphological and ecological attributes. It is distinguished from *N. dulcis* principally by the subrostrate rather than rounded ends.



Water-quality profile:

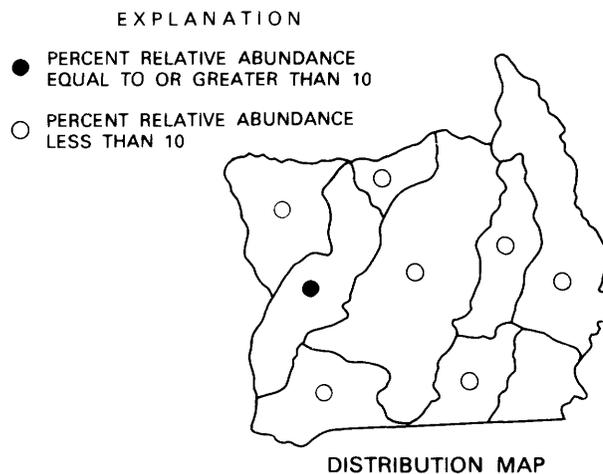
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	76	576–11000	2070– 2070	2070(10.5)
pH (units)	76	8.00– 8.73	8.12– 8.12	8.12(10.5)
Temperature ( $^{\circ}\text{C}$ )	76	2.5– 30.2	17.0– 17.0	17.0(10.5)
Turbidity (NTU)	75	0.5– 435	7.2– 7.2	7.2(10.5)
Oxygen, dissolved (mg/L)	55	0.80– 19.0	6.88– 6.88	6.88(10.5)
Biochemical oxygen demand (mg/L)	17	0.5– 8.3	-----	2.2(2.9)
Hardness, total (mg/L $\text{CaCO}_3$ )	53	238– 3490	782– 782	782(10.5)
Calcium, dissolved (mg/L)	53	40.0– 328	84.6– 84.6	84.6(10.5)
Magnesium, dissolved (mg/L)	53	33.5– 645	138– 138	138(10.5)
Sodium, dissolved (mg/L)	54	11.5– 1950	202– 202	202(10.5)
Bicarbonate (mg/L)	56	198– 755	715– 715	715(10.5)
Carbonate (mg/L)	14	1.0– 29.0	-----	8.4(4.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	56	162– 619	586– 586	586(10.5)
Sulfate, dissolved (mg/L)	54	83– 6900	604– 604	604(10.5)
Chloride, dissolved (mg/L)	54	1.2– 126	16.6– 16.6	16.6(10.5)
Fluoride, dissolved (mg/L)	51	0.1– 1.5	0.3– 0.3	0.3(10.5)
Dissolved solids, calculated (mg/L)	53	568–10400	1760– 1760	1760(10.5)
Sediment, total suspended (mg/L)	68	0.2– 893	28.4– 28.4	28.4(10.5)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	31	0.01– 0.64	-----	0.37(5.2)
Nitrogen, total ammonia (mg/L as N)	47	0.01– 0.57	0.03– 0.03	0.03(10.5)
Phosphorus, total (mg/L as P)	56	0.010– 0.62	0.060–0.060	0.060(10.5)
Phosphorus, total ortho (mg/L as P)	56	0.002– 0.52	0.12– 0.12	0.12(10.5)
Iron, total recoverable (mg/L)	27	0.04– 0.75	0.50– 0.50	0.50(10.5)
Manganese, total recoverable (mg/L)	28	0.005– 0.39	0.39– 0.39	0.39(10.5)

Ecological summary:

Prefers slightly brackish water; pH greater than 8.00 (alkalibiontic); substrate the size of fine gravel (0.2– to 1–cm diameter); and small streams (less than 1  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft) in the study area. Tolerates small amounts of suspended sediment, turbidity, and chloride. Summer (August) dominant but occurs in all seasons.

Distribution summary:

Widespread; found in 82 collections from 31 sites in the study area. Best population development in Davis Creek near Busby (station 21).



ECOTYPE: *NAVICULA GREGARIA* DONK.

Biotype(s):

\**N. gregaria* Donk. var. *gregaria*  
*N. secreta* var. *apiculata* Patr.

Reference:

Patrick and Reimer, 1966 (p. 467; pl. 44, fig. 6)

Herbarium slide number:

1-3-11

Mean percent relative abundance:

1.8

Percent occurrence:

78.6

Abundance-occurrence index:

144.6

Preferred percent occurrence:

3.2

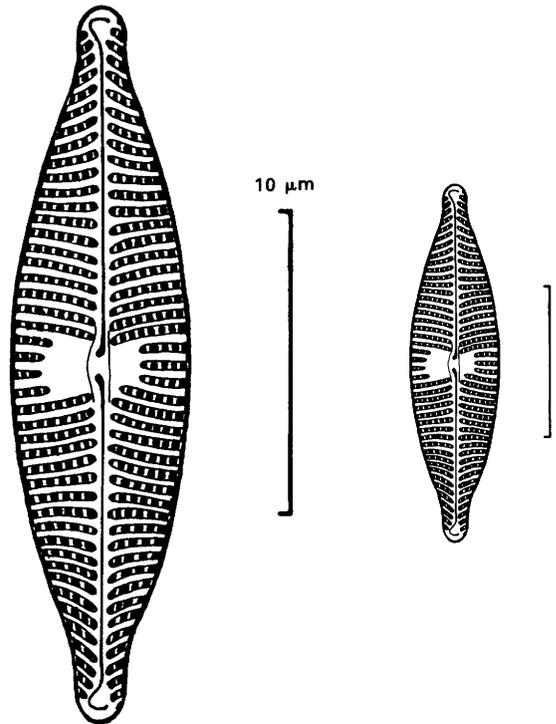
Maximum percent relative abundance:

35.5

Station number: 8

Date: June 19, 1980

Type of collection: E



Description:

Striae, 19–21 in 10  $\mu\text{m}$ . Length, 23.8  $\mu\text{m}$ . Width, 6.0  $\mu\text{m}$ . The ecotype is distinguished by nearly parallel striae and protracted ends. In our material we have forms spanning both biotypes, often in one collection. Valve shape varies from lanceolate to linear-lanceolate; ends vary from protracted-rostrate to somewhat capitate; and central areas range from a slight broadening of the axial area to one that is distinctly transverse and rectangular, though often asymmetrical. The principal author believes that the two biotypes are different expressions of the same genome.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	241	239-11000	1300- 2450	1410(26.2)
pH (units) -----	240	7.50- 8.73	8.10- 8.35	8.30(26.2)
Temperature ( $^{\circ}\text{C}$ ) -----	240	1.7- 30.5	12.3- 16.4	16.4(26.2)
Turbidity (NTU) -----	241	0.5- 3250	1.8- 16	7.0(26.2)
Oxygen, dissolved (mg/L) -----	175	3.82- 19.0	7.92- 12.6	12.6(26.2)
Biochemical oxygen demand (mg/L) -----	69	0.8- 8.3	1.4- 2.3	1.5(26.2)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	145	123- 3490	506- 1070	719(26.2)
Calcium, dissolved (mg/L) -----	145	16.0- 330	81.7- 110	85.1(26.2)
Magnesium, dissolved (mg/L)-----	145	15.1- 645	71.0- 194	123(26.2)
Sodium, dissolved (mg/L) -----	154	9.5- 1950	77.8- 238	77.8(26.2)
Bicarbonate (mg/L)-----	161	45- 816	473- 754	488(26.2)
Carbonate (mg/L) -----	34	0.5- 29.0	4.1- 4.1	4.1(19.5)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	161	39- 669	388- 618	400(26.2)
Sulfate, dissolved (mg/L) -----	154	38- 6900	267- 875	475(26.2)
Chloride, dissolved (mg/L) -----	154	0.4- 174	0.4- 6.4	3.8(26.2)
Fluoride, dissolved (mg/L) -----	149	0.04- 1.7	0.4- 1.2	0.5(26.2)
Dissolved solids, calculated (mg/L) -----	145	254-10400	1140- 2180	1250(26.2)
Sediment, total suspended (mg/L) -----	219	0.2- 8260	1.9- 37.4	16.1(26.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	114	0.01- 0.71	0.01- 0.39	0.01(26.2)
Nitrogen, total ammonia (mg/L as N) -----	139	0.01- 0.57	0.01- 0.02	0.01(26.2)
Phosphorus, total (mg/L as P)-----	165	0.010- 3.7	0.020-0.068	0.020(26.2)
Phosphorus, total ortho (mg/L as P)-----	166	0.001- 2.5	0.004-0.064	0.004(26.2)
Iron, total recoverable (mg/L)-----	94	0.02- 2.1	0.02- 0.60	0.21(26.2)
Manganese, total recoverable (mg/L)-----	84	0.005- 0.41	0.025- 0.24	0.065(26.2)

Ecological summary:

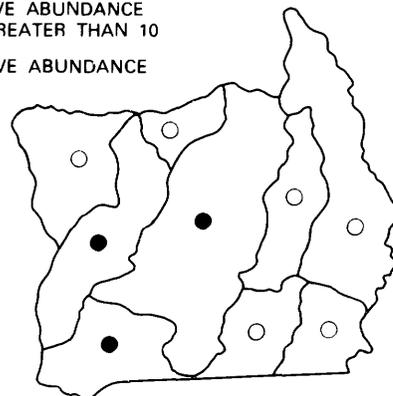
Prefers cool, extremely hard, slightly brackish waters; pH of 8.10 to 8.35; fine sand or larger (greater than 0.05-mm diameter); and medium streams (1 to 100  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 4,000 ft). Tolerates some suspended sediment and turbidity. Spring (May and June) dominant.

Distribution summary:

Found throughout the study area. Best population development in certain tributaries of Rosebud Creek and the Tongue River.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NAVICULA ODIOSA* WALLACE

Biotype(s):

*N. odiosa* Wallace var. *odiosa*

Reference:

Patrick and Reimer, 1966 (p. 510; pl. 48, fig. 18)

Herbarium slide number:

1-3-13

Mean percent relative abundance:

0.6

Percent occurrence:

34.3

Abundance-occurrence index:

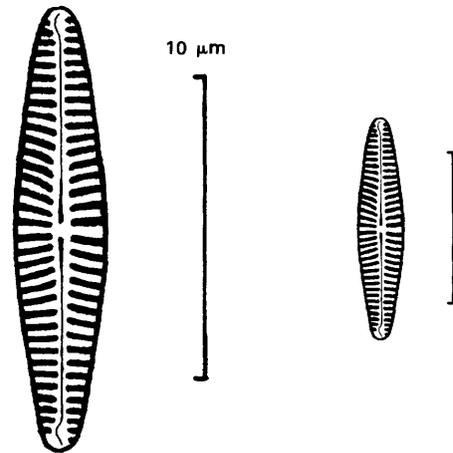
19.5

Preferred percent occurrence:

1.6

Maximum percent relative abundance:

20.2



Station number: 46

Date: July 24, 1979

Type of collection: F

Description:

Striae, 22-24 in 10  $\mu\text{m}$ . Length, 14.8  $\mu\text{m}$ . Width, 3.0  $\mu\text{m}$ . A small *Navicula* with fine, radiate to parallel striae and a central area that is only a bit wider than the axial area. Our specimens are somewhat less linear and more lanceolate than those described by Patrick and Reimer (1966); otherwise, the features are the same.

Water-quality profile:

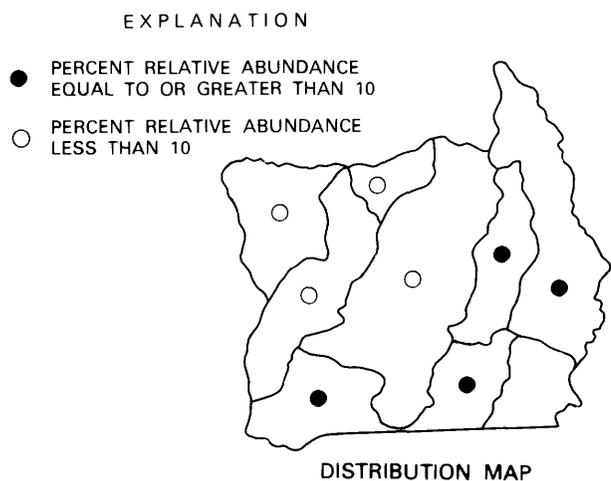
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	117	462–11000	1690–6100	1690(20.2)
pH (units) -----	117	7.50– 8.73	8.08– 8.40	8.14(20.2)
Temperature ( $^{\circ}\text{C}$ ) -----	115	1.3– 30.5	10.5– 24.0	24.0(20.2)
Turbidity (NTU) -----	117	0.7– 4200	2.3– 435	435(20.2)
Oxygen, dissolved (mg/L) -----	76	0.80– 19.0	9.50– 10.7	9.50(16.9)
Biochemical oxygen demand (mg/L) -----	28	0.8– 8.3	1.5– 1.5	1.5(16.9)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	72	123– 3490	556– 632	556(20.2)
Calcium, dissolved (mg/L) -----	72	16.0– 330	138– 143	138(20.2)
Magnesium, dissolved (mg/L) -----	72	18.3– 645	51.0– 69.5	51.0(20.2)
Sodium, dissolved (mg/L) -----	76	18.3– 1950	170– 298	170(20.2)
Bicarbonate (mg/L) -----	78	148– 913	198– 261	198(20.2)
Carbonate (mg/L) -----	22	0.5– 29.0	-----	18.0(4.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	78	133– 748	162– 214	162(20.2)
Sulfate, dissolved (mg/L) -----	76	41– 6900	617– 835	617(20.2)
Chloride, dissolved (mg/L) -----	76	1.2– 174	88.9– 174	88.9(20.2)
Fluoride, dissolved (mg/L) -----	72	0.04– 1.7	1.5– 1.5	1.5(12.6)
Dissolved solids, calculated (mg/L) -----	72	398–10400	1260–1700	1260(20.2)
Sediment, total suspended (mg/L) -----	111	0.7– 8260	1.7– 893	893(20.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	52	0.01– 0.66	0.05– 0.32	0.32(20.2)
Nitrogen, total ammonia (mg/L as N) -----	78	0.01– 0.57	0.01– 0.11	0.01(20.2)
Phosphorus, total (mg/L as P) -----	90	0.010– 3.7	0.040– 0.60	0.60(20.2)
Phosphorus, total ortho (mg/L as P) -----	87	0.001– 2.5	0.016– 0.38	0.38(20.2)
Iron, total recoverable (mg/L) -----	37	0.07– 2.1	0.36– 0.36	0.36(11.8)
Manganese, total recoverable (mg/L) -----	34	0.010– 0.41	0.10– 0.10	0.10(11.8)

Ecological summary:

Prefers very hard, brackish water with relatively large amounts of chloride (88 to 174 mg/L); and a pH of 8.00 to 8.40; but is apparently indifferent to substrate particle size, stream size, and elevation. Eurythermal between 10 to 24  $^{\circ}\text{C}$ . Tolerates considerable suspended sediment and turbidity. Summer and fall (July to October) dominant.

Distribution summary:

Widespread. Best population development in Mizpah Creek, the Powder River, and Deer Creek near Decker (station 22).



ECOTYPE: *NAVICULA PAVILLARDII* HUST.

Biotype(s):

*N. pavillardii* Hust. var. *pavillardii*

Reference:

Hustedt, 1939 (p. 635; figs. 86–90)

Herbarium slide number:

1-1-2

Mean percent relative abundance:

0.2

Percent occurrence:

3.5

Abundance-occurrence index:

0.7

Preferred percent occurrence:

0.8

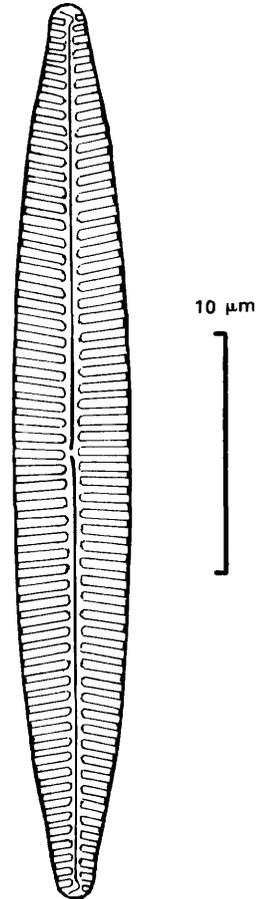
Maximum percent relative abundance:

19.3

Station number: 6

Date: August 9, 1979

Type of collection: E



Description:

Striae, 14–17 in 10  $\mu\text{m}$ . Length, 37.3  $\mu\text{m}$ . Width, 5.0  $\mu\text{m}$ . A very delicate and lightly silicified *Navicula*. Not easily confused with any other diatom in the study area.

## Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	13	571-7030	3080- 6000	6000(19.3)
pH (units) -----	13	8.10- 8.73	8.55- 8.73	8.55(19.3)
Temperature ( $^{\circ}\text{C}$ ) -----	13	4.8- 30.2	21.4- 29.2	27.5(19.3)
Turbidity (NTU) -----	13	1.5- 132	10.0- 35	10.0(19.3)
Oxygen, dissolved (mg/L) -----	10	8.10- 19.0	11.2- 19.0	19.0(19.3)
Biochemical oxygen demand (mg/L) -----	2	2.2- 2.7	-----	2.2(1.2)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	10	190-2040	238- 829	829(19.3)
Calcium, dissolved (mg/L) -----	10	35.7- 254	35.7- 78.6	78.6(19.3)
Magnesium, dissolved (mg/L)-----	10	18.3- 342	33.5- 153	153(19.3)
Sodium, dissolved (mg/L) -----	11	56.5-1470	654- 1230	1230(19.3)
Bicarbonate (mg/L)-----	11	148- 755	531- 597	541(19.3)
Carbonate (mg/L) -----	8	7.2- 29.0	19.0- 26.0	19.0(19.3)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	11	133- 619	470- 533	475(19.3)
Sulfate, dissolved (mg/L) -----	11	165-5450	1120- 2780	2780(19.3)
Chloride, dissolved (mg/L) -----	11	2.2- 28.0	15.3- 20.0	19.8(19.3)
Fluoride, dissolved (mg/L) -----	10	0.3- 0.6	0.5- 0.6	0.5(19.3)
Dissolved solids, calculated (mg/L) -----	10	448-7680	2420- 4820	4820(19.3)
Sediment, total suspended (mg/L) -----	13	1.4- 255	22.4- 55.5	22.4(19.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	5	0.01- 0.11	-----	0.04(1.9)
Nitrogen, total ammonia (mg/L as N) -----	10	0.01- 0.21	0.03- 0.21	0.21(19.3)
Phosphorus, total (mg/L as P)-----	11	0.010- 0.20	0.030-0.070	0.030(19.3)
Phosphorus, total ortho (mg/L as P)-----	10	0.003- 0.11	0.021-0.032	0.021(19.3)
Iron, total recoverable (mg/L)-----	5	0.16- 0.46	0.46- 0.46	0.46(16.8)
Manganese, total recoverable (mg/L)-----	5	0.035- 0.36	0.095-0.095	0.095(16.8)

## Ecological summary:

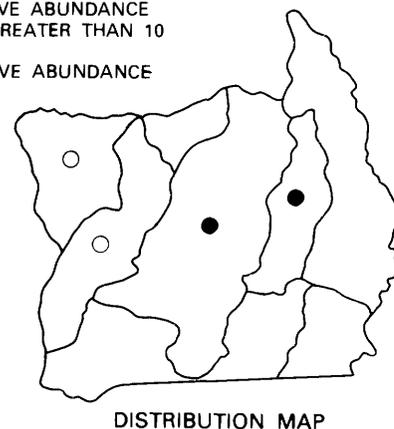
Prefers brackish, sodium sulfate waters; warm temperatures (mesothermal between 21 and 30 $^{\circ}\text{C}$ ); pH greater than 8.10 (alkalibiontic); dissolved-oxygen content greater than 8.10 mg/L; coarse sand substrates or larger (greater than 0.3-mm diameter); and small streams (0 to 1 ft<sup>3</sup>/s) at lower elevations (less than 2,500 ft) in the study area. Tolerates some suspended sediment, turbidity, and chloride. Summer (August) dominant.

## Distribution summary:

Found only in the downstream reaches of Rosebud Creek, Armells Creek, Pumpkin Creek, and Mizpah Creek, with good population development (greater than 10 percent relative abundance) in the last two streams. Elsewhere in eastern Montana, this taxon achieves greater abundance.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



ECOTYPE: *NAVICULA PEREGRINA* VAR. *LANCEOLATA* SKVORTZOW

Biotype(s):

*N. peregrina* var. *lanceolata* Skvortzow

Reference:

Skvortzow, 1929 (p. 22; figs. 14-15)

Herbarium slide number:

1-3-12

Mean percent relative abundance:

0.2

Percent occurrence:

1.4

Abundance-occurrence index:

0.3

Preferred percent occurrence:

0.5

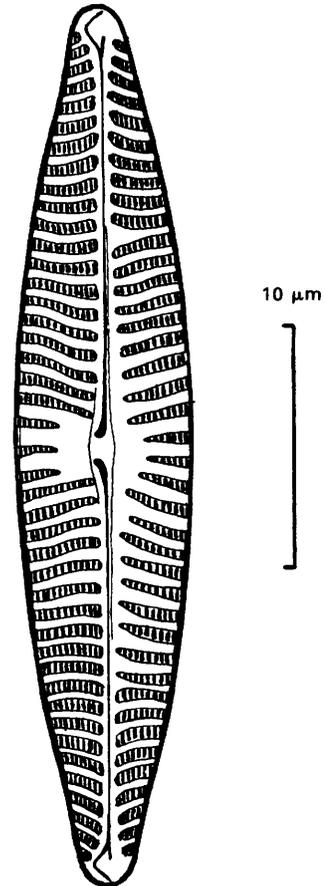
Maximum percent relative abundance:

49.1

Station number: 21

Date: September 8, 1978

Type of collection: E



Description:

Striae, 10-13 in 10  $\mu\text{m}$ . Length, 36.5  $\mu\text{m}$ . Width, 7.5  $\mu\text{m}$ . Distinguished from the nominate variety by its smaller size and finer striae. Distinguished from *N. viridula* var. *avenacea* by the transverse rather than rounded central area.

Water-quality profile:

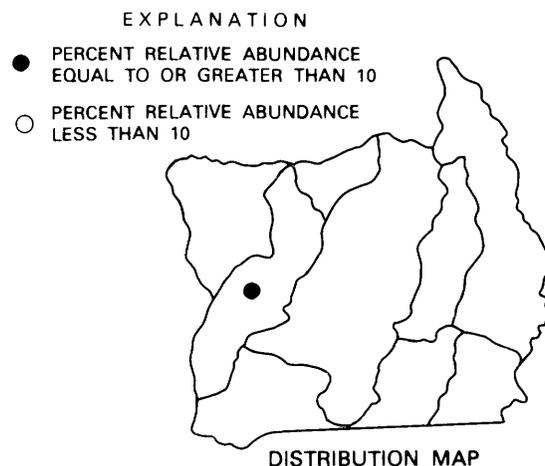
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	5	1530– 2460	2070– 2450	2450(49.1)
pH (units) -----	5	8.12– 8.20	8.12– 8.20	8.20(49.1)
Temperature ( $^{\circ}\text{C}$ ) -----	5	16.4– 21.2	16.4– 17.0	16.4(49.1)
Turbidity (NTU) -----	5	1.2– 7.2	1.8– 7.2	1.8(49.1)
Oxygen, dissolved (mg/L) -----	4	6.88– 12.0	6.88– 6.88	6.88(31.0)
Biochemical oxygen demand (mg/L) -----	1	7.8– 7.8	-----	7.8(3.0)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	5	586– 1070	782– 1070	1070(49.1)
Calcium, dissolved (mg/L) -----	5	83.2– 110	84.6– 110	110(49.1)
Magnesium, dissolved (mg/L) -----	5	81.2– 194	138– 194	194(49.1)
Sodium, dissolved (mg/L) -----	5	117– 356	202– 238	238(49.1)
Bicarbonate (mg/L) -----	5	492– 754	715– 754	754(49.1)
Carbonate (mg/L) -----	0	-----	-----	-----
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	5	403– 618	586– 618	618(49.1)
Sulfate, dissolved (mg/L) -----	5	440– 899	604– 875	875(49.1)
Chloride, dissolved (mg/L) -----	5	4.4– 18.6	6.2– 16.6	6.2(49.1)
Fluoride, dissolved (mg/L) -----	5	0.3– 0.5	0.3– 0.4	0.4(49.1)
Dissolved solids, calculated (mg/L) -----	5	1370– 2180	1760– 2180	2180(49.1)
Sediment, total suspended (mg/L) -----	5	2.3– 28.4	3.5– 28.4	3.5(49.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	3	0.03– 0.12	0.12– 0.12	0.12(49.1)
Nitrogen, total ammonia (mg/L as N) -----	5	0.02– 0.11	0.02– 0.03	0.02(49.1)
Phosphorus, total (mg/L as P) -----	5	0.011– 0.084	0.060– 0.060	0.060(49.1)
Phosphorus, total ortho (mg/L as P) -----	5	0.004– 0.12	0.028– 0.12	0.028(49.1)
Iron, total recoverable (mg/L) -----	4	0.22– 0.50	0.47– 0.50	0.47(49.1)
Manganese, total recoverable (mg/L) -----	4	0.090– 0.39	0.24– 0.39	0.24(49.1)

Ecological summary:

Prefers cool, extremely hard, slightly brackish waters; pH of 8.10 to 8.20 (alkalibiontic); fine gravels (0.2– to 1–cm diameter); and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 3,500 ft) in the study area. Tolerates small concentrations of chloride, suspended sediment, and turbidity. Late summer (August and September) dominant.

Distribution summary:

Found to date only in Davis Creek near Busby (station 21). *N. peregrina* var. *peregrina* (Ehr.) Kutz. occurs frequently throughout the study area, but never in large numbers.



ECOTYPE: *NAVICULA RADIOSA* VAR. *TENELLA* (Breb. ex Kutz.) GRUN.

Biotype(s):

*N. radiosa* var. *tenella* (Breb. ex Kutz.) Grun.

Reference:

Patrick and Reimer, 1966 (p. 510; pl. 48, fig. 17)

Herbarium slide number:

1-3-9

Mean percent relative abundance:

1.1

Percent occurrence:

51.1

Abundance-occurrence index:

55.4

Preferred percent occurrence:

1.4

Maximum percent relative abundance:

25.0

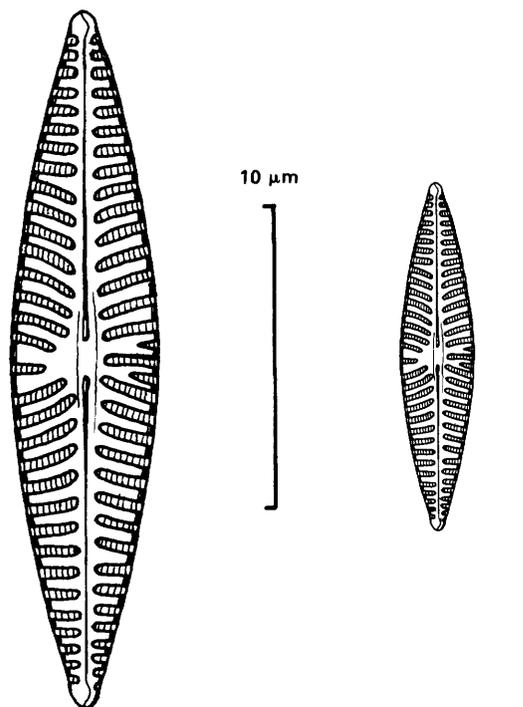
Station number: 7

Date: August 3, 1978

Type of collection: E

Description:

Striae, 13-17 in 10  $\mu\text{m}$ . Length, 23.0  $\mu\text{m}$ . Width, 5.0  $\mu\text{m}$ . A small, highly variable *Navicula*. Valve shape may range from linear-lanceolate to lanceolate to elliptical-lanceolate. The ends may be acute or slightly apiculate. The axial area in our specimens is not thickly silicified, as it is in *N. radiosa* Kutz. The central area occasionally is formed by the median striae being longer than the rest and extending almost to the central nodule (as in *N. salinarum* var. *intermedia*), but more often it is formed by one or two irregularly shortened striae. The striae count may range from 11 to 18 in 10  $\mu\text{m}$ , depending on the population and the individual frustule selected. The principal author can find no convincing evidence why this taxon should be included under *N. radiosa* and believes it is more closely related to *N. salinarum* var. *intermedia*, with which it is frequently associated in nature. See description of *N. salinarum* var. *intermedia*.



Water-quality profile:

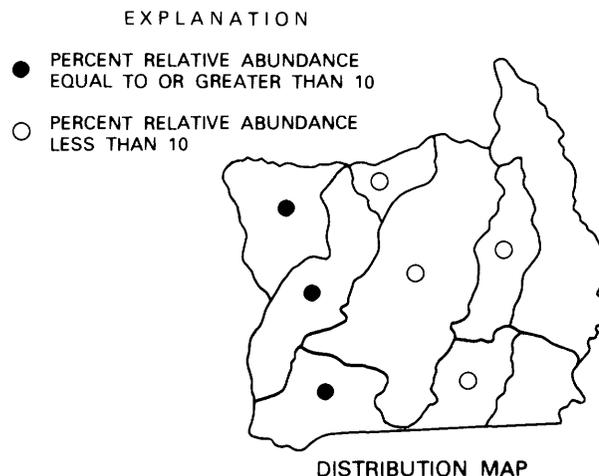
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	150	239-11000	239- 890	818(25.0)
pH (units) -----	150	7.70- 8.73	7.97- 8.38	8.30(25.0)
Temperature ( $^{\circ}\text{C}$ ) -----	149	1.0- 30.5	12.0- 21.2	15.0(25.0)
Turbidity (NTU) -----	147	0.5- 3250	11- 94	11(25.0)
Oxygen, dissolved (mg/L) -----	105	6.20- 15.3	7.70- 9.10	9.10(20.2)
Biochemical oxygen demand (mg/L) -----	38	1.0- 8.9	1.0- 2.2	1.0(20.2)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	93	123- 3490	375- 484	484(25.0)
Calcium, dissolved (mg/L) -----	93	16.0- 328	69.6- 77.0	77.0(25.0)
Magnesium, dissolved (mg/L)-----	93	13.5- 645	48.9- 71.0	71.0(25.0)
Sodium, dissolved (mg/L) -----	96	9.1- 1950	12.8- 43.2	19.9(25.0)
Bicarbonate (mg/L)-----	103	45- 913	392- 441	441(25.0)
Carbonate (mg/L) -----	25	0.5- 21.0	2.0- 2.0	2.0(11.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	103	39- 748	321- 362	362(25.0)
Sulfate, dissolved (mg/L) -----	96	34- 6900	69- 181	165(25.0)
Chloride, dissolved (mg/L) -----	96	1.3- 174	2.4- 3.7	2.5(25.0)
Fluoride, dissolved (mg/L) -----	93	0.1- 1.5	0.6- 0.9	0.6(25.0)
Dissolved solids, calculated (mg/L) -----	93	196-10400	596- 777	777(25.0)
Sediment, total suspended (mg/L) -----	140	0.2- 8260	21.2- 193	21.2(25.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	80	0.01- 0.71	0.08- 0.08	0.08(18.4)
Nitrogen, total ammonia (mg/L as N) -----	88	0.01- 0.30	0.02- 0.02	0.02(18.4)
Phosphorus, total (mg/L as P)-----	113	0.010- 3.7	0.064-0.064	0.064(18.4)
Phosphorus, total ortho (mg/L as P)-----	114	0.001- 2.5	0.023-0.023	0.023(18.4)
Iron, total recoverable (mg/L)-----	57	0.02- 1.4	0.59- 0.59	0.59(18.4)
Manganese, total recoverable (mg/L)-----	55	0.005- 0.26	0.095-0.095	0.095(18.4)

Ecological summary:

Prefers cool, fresh, very hard waters with relatively small concentrations of sodium and sulfate; fine to medium gravels (0.2- to 3-cm diameter); and larger streams (10 to 100  $\text{ft}^3/\text{s}$ ) at higher elevations in the study area (3,500 to 4,000 ft). Tolerates some suspended sediment and turbidity. Sensitive to small concentrations of chloride. Summer (July to September) dominant.

Distribution summary:

Found in all except the Little Powder and Lower Powder hydrologic units. Best population development in the western part of the study area.



ECOTYPE: *NAVICULA RHYNCHOCEPHALA* KUTZ.

Biotype(s):

*N. rhyngocephala* Kutz. var. *rhyngocephala*  
*N. rhyngocephala* var. *amphiceros* (Kutz.) Grun.  
\**N. rhyngocephala* var. *germainii* (Wallace) Patr.

Reference:

Patrick and Reimer, 1966 (p. 506; pl. 48, fig. 8)

Herbarium slide number:

1-3-14

Mean percent relative abundance:

0.2

Percent occurrence:

19.7

Abundance-occurrence index:

4.3

Preferred percent occurrence:

0.3

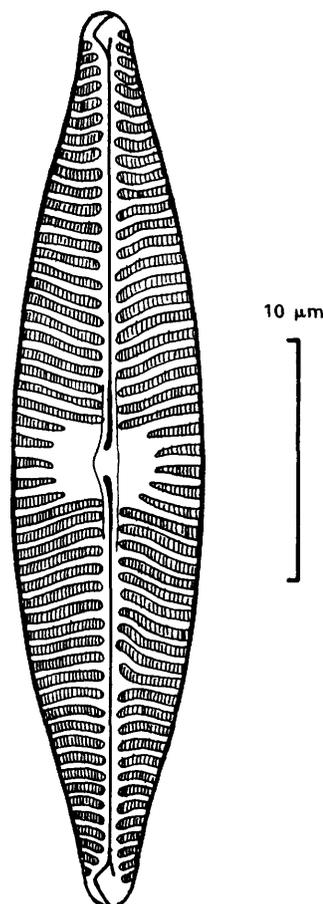
Maximum percent relative abundance:

31.2

Station number: 21

Date: July 25, 1978

Type of collection: E



Description:

Striae, 13-16 in 10  $\mu\text{m}$ . Length, 37.2  $\mu\text{m}$ . Width, 8.0  $\mu\text{m}$ . A medium *Navicula* with protracted ends, coarse striae, and a large, rounded central area. Axial area and central nodule more thickly silicified than the rest of the valve. Differs from *N. cincta* var. *rostrata* by having a larger central area and a larger overall size. Distinguished from *N. gregaria* by its larger size and coarser striae. Distinguished from *N. salinarum* var. *intermedia* by its rounded rather than irregular central area and from *N. viridula* var. *avenacea* by its protracted rather than rounded ends.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	61	239-7030	1670- 1670	1670(31.2)
pH (units) -----	61	7.80- 8.73	8.20- 8.20	8.20(31.2)
Temperature ( $^{\circ}\text{C}$ ) -----	61	1.3- 29.2	21.2- 21.2	21.2(31.2)
Turbidity (NTU) -----	58	0.9- 435	1.2- 1.2	1.2(31.2)
Oxygen, dissolved (mg/L) -----	44	5.40- 15.0	7.65- 7.65	7.65(31.2)
Biochemical oxygen demand (mg/L) -----	15	0.5- 7.8	7.8- 7.8	7.8(31.2)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	27	190-1250	752- 752	752(31.2)
Calcium, dissolved (mg/L) -----	27	35.7- 165	83.2- 83.2	83.2(31.2)
Magnesium, dissolved (mg/L)-----	27	18.3- 204	132- 132	132(31.2)
Sodium, dissolved (mg/L) -----	29	31.1-1470	131- 131	131(31.2)
Bicarbonate (mg/L)-----	35	148- 913	623- 623	623(31.2)
Carbonate (mg/L) -----	11	0.5- 29.0	-----	29.0(2.8)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	35	133- 748	511- 511	511(31.2)
Sulfate, dissolved (mg/L) -----	29	116-3400	454- 454	454(31.2)
Chloride, dissolved (mg/L) -----	29	1.2- 88.9	4.4- 4.4	4.4(31.2)
Fluoride, dissolved (mg/L) -----	26	0.3- 1.2	0.3- 0.3	0.3(31.2)
Dissolved solids, calculated (mg/L) -----	27	416-5800	1430- 1430	1430(31.2)
Sediment, total suspended (mg/L) -----	56	1.5- 893	2.3- 2.3	2.3(31.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	29	0.01- 0.32	0.03- 0.03	0.03(31.2)
Nitrogen, total ammonia (mg/L as N) -----	36	0.01- 0.11	0.02- 0.02	0.02(31.2)
Phosphorus, total (mg/L as P)-----	42	0.010- 0.60	0.078-0.078	0.078(31.2)
Phosphorus, total ortho (mg/L as P)-----	44	0.002- 0.38	0.045-0.045	0.045(31.2)
Iron, total recoverable (mg/L)-----	21	0.04- 2.1	0.22- 0.22	0.22(31.2)
Manganese, total recoverable (mg/L)-----	19	0.015- 0.39	0.12- 0.12	0.12(31.2)

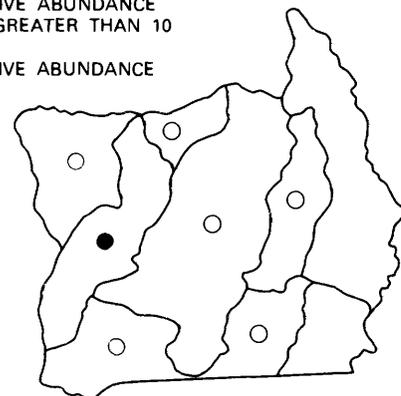
Ecological summary:

Prefers very hard, slightly brackish waters; sand substrates (0.05- to 2-mm diameter); and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 3,500 ft) in the study area. Appears to be sensitive to small amounts of suspended sediment, turbidity, and chloride. Summer (July to September) dominant.

Distribution summary:

Found in all hydrologic units except those representing the downstream drainage of the Powder River and the Little Powder River. Best population development in Davis Creek near Busby (station 21).

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NAVICULA SALINARUM* VAR. *INTERMEDIA* (GRUN.) CL.

Biotype(s):

*N. salinarum* var. *intermedia* (Grun.) Cl.

Reference:

Patrick and Reimer, 1966 (p. 503; pl. 48, fig. 2)

Herbarium slide number:

1-3-8

Mean percent relative abundance:

1.4

Percent occurrence:

47.3

Abundance-occurrence index:

66.3

Preferred percent occurrence:

3.2

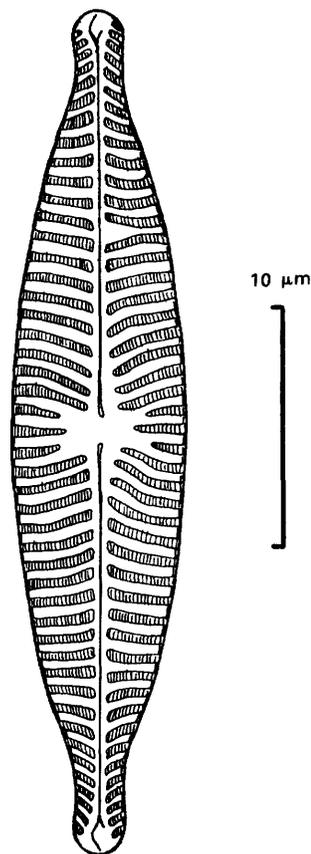
Maximum percent relative abundance:

31.0

Station number: 8

Date: August 26, 1978

Type of collection: E



Description:

Striae, 13-15 in 10  $\mu\text{m}$ . Length, 35.0  $\mu\text{m}$ . Width, 7.4  $\mu\text{m}$ . Distinguished from other varieties of *Navicula* by the protracted, subcapitate to capitate ends and the irregular central area formed by striae being alternately longer and shorter. The principal author questions the association of this taxon with *N. salinarum* Grun., which has a lanceolate-elliptical central area and a largely exclusive ecological amplitude. This taxon may belong more appropriately with *N. radiosa* var. *tenella* by virtue of its similar habitus and frequent association. See description of *N. radiosa* var. *tenella*.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	129	239-5910	662- 2350	2140(31.0)
pH (units) -----	128	7.70- 8.73	8.10- 8.40	8.40(31.0)
Temperature ( $^{\circ}\text{C}$ ) -----	131	1.7- 30.5	13.3- 20.5	19.8(31.0)
Turbidity (NTU) -----	125	0.5-4200	1.0- 60	3.5(31.0)
Oxygen, dissolved (mg/L) -----	93	7.00- 15.0	7.60- 9.42	8.38(29.3)
Biochemical oxygen demand (mg/L) -----	39	0.7- 8.9	1.0- 1.0	1.0(26.6)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	74	123-1430	371- 986	986(31.0)
Calcium, dissolved (mg/L) -----	74	16.0- 192	57.6- 126	98.0(31.0)
Magnesium, dissolved (mg/L)-----	74	13.5- 242	45.7- 180	180(31.0)
Sodium, dissolved (mg/L) -----	79	9.1- 662	12.8- 188	188(31.0)
Bicarbonate (mg/L)-----	85	111- 776	335- 488	488(31.0)
Carbonate (mg/L) -----	23	0.5- 24.0	6.7- 7.2	7.2(31.0)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	85	91- 636	275- 412	412(31.0)
Sulfate, dissolved (mg/L) -----	79	34-2390	67- 918	918(31.0)
Chloride, dissolved (mg/L) -----	79	1.2- 174	2.4- 51.0	4.9(31.0)
Fluoride, dissolved (mg/L) -----	76	0.1- 1.7	0.5- 0.9	0.5(31.0)
Dissolved solids, calculated (mg/L) -----	74	196-4020	569- 1880	1880(31.0)
Sediment, total suspended (mg/L) -----	122	0.6-3220	1.7- 139	8.1(31.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	71	0.01- 0.53	0.02- 0.17	0.05(31.0)
Nitrogen, total ammonia (mg/L as N) -----	74	0.01- 0.15	0.01- 0.05	0.02(31.0)
Phosphorus, total (mg/L as P)-----	97	0.010- 2.6	0.017- 0.15	0.020(31.0)
Phosphorus, total ortho (mg/L as P)-----	97	0.001- 1.8	0.007-0.080	0.007(31.0)
Iron, total recoverable (mg/L)-----	57	0.04- 1.4	0.07- 0.83	0.16(31.0)
Manganese, total recoverable (mg/L)-----	51	0.010- 0.26	0.015- 0.11	0.055(31.0)

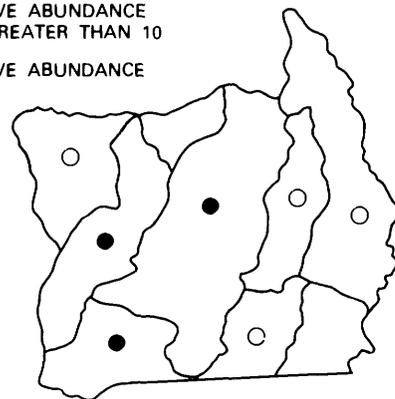
Ecological summary:

Prefers cool, fresh to slightly brackish waters relatively rich in magnesium and bicarbonate ions; fine gravels or larger (greater than 0.2-cm diameter); and medium streams (0.1 to 100  $\text{ft}^3/\text{s}$ ) at higher elevations (3,500 to 4,000 ft). Tolerates some suspended sediment, turbidity, and chloride. Summer (June to September) dominant.

Distribution summary:

Widespread. Best population development in the Rosebud Creek and Tongue River drainages.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NAVICULA SYMMETRICA* PATR.

Biotype(s):

*N. schroeteri* var. *escambia* Patr.

\**N. symmetrica* Patr. var. *symmetrica*

Reference:

Patrick and Reimer, 1966 (p. 513; pl. 49, fig. 2)

Herbarium slide number:

1-3-15

Mean percent relative abundance:

0.4

Percent occurrence:

22.7

Abundance-occurrence index:

9.8

Preferred percent occurrence:

0.8

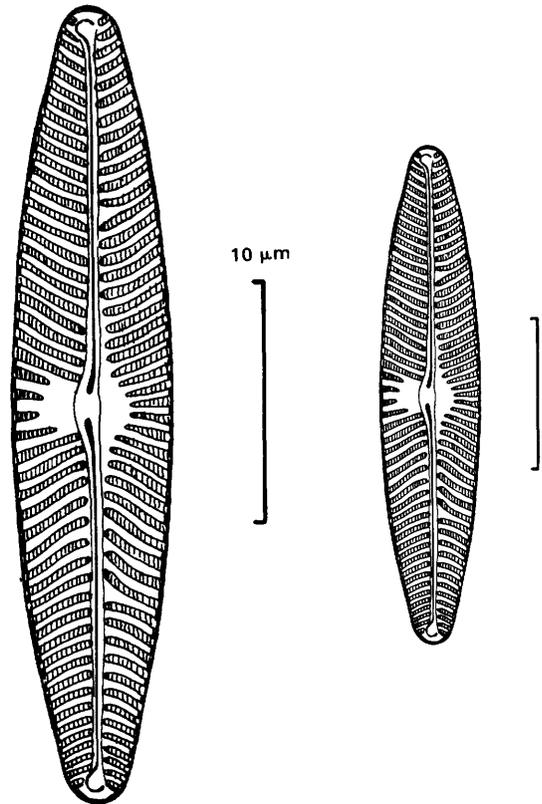
Maximum percent relative abundance:

31.5

Station number: 28

Date: August 16, 1978

Type of collection: E



Description:

Striae, 13-17 in 10  $\mu\text{m}$ . Length, 33.0  $\mu\text{m}$ . Width, 6.6  $\mu\text{m}$ . Distinguished by striae that are radiate throughout the valve. Specimens matching the descriptions for each biotype often are found together in our collections; consequently we believe that they are different expressions of the same genome.

## Water-quality profile:

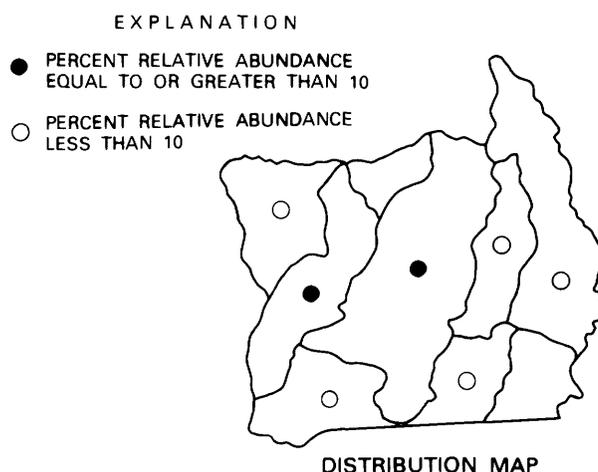
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu$ mho/cm)-----	71	239-6400	838- 1450	838(31.5)
pH (units) -----	71	7.85- 8.72	8.22- 8.42	8.40(31.5)
Temperature ( $^{\circ}$ C) -----	70	2.4- 30.5	16.5- 21.9	16.5(31.5)
Turbidity (NTU) -----	68	0.7-4200	15- 53	17(31.5)
Oxygen, dissolved (mg/L) -----	47	6.78- 15.0	9.10- 9.10	9.10(31.5)
Biochemical oxygen demand (mg/L) -----	16	0.7- 8.9	-----	3.6(4.2)
Hardness, total (mg/L CaCO <sub>3</sub> ) -----	42	123-3320	404- 617	406(31.5)
Calcium, dissolved (mg/L) -----	42	16.0- 330	57.6- 63.2	57.6(31.5)
Magnesium, dissolved (mg/L)-----	42	15.1- 605	61.0- 112	64.0(31.5)
Sodium, dissolved (mg/L) -----	43	9.5- 665	55.0- 133	55.0(31.5)
Bicarbonate (mg/L)-----	48	22- 776	460- 481	481(31.5)
Carbonate (mg/L) -----	16	1.0- 24.0	7.0- 7.0	7.0(10.8)
Alkalinity, total (mg/L CaCO <sub>3</sub> ) -----	48	39- 636	389- 394	394(31.5)
Sulfate, dissolved (mg/L) -----	43	43-4040	116- 481	116(31.5)
Chloride, dissolved (mg/L) -----	43	0.4- 174	3.2- 7.0	7.0(31.5)
Fluoride, dissolved (mg/L) -----	40	0.1- 1.7	0.6- 1.0	0.9(31.5)
Dissolved solids, calculated (mg/L) -----	42	254-6290	782- 1260	782(31.5)
Sediment, total suspended (mg/L) -----	68	1.2-3220	16.7- 102	16.7(31.5)
Nitrogen, total NO <sub>2</sub> +NO <sub>3</sub> (mg/L as N)-----	34	0.01- 0.42	0.01- 0.02	0.02(31.5)
Nitrogen, total ammonia (mg/L as N) -----	43	0.01- 0.15	0.01- 0.03	0.03(12.3)
Phosphorus, total (mg/L as P)-----	52	0.012- 2.6	0.040-0.078	0.040(31.5)
Phosphorus, total ortho (mg/L as P)-----	52	0.001- 1.8	0.008-0.012	0.012(31.5)
Iron, total recoverable (mg/L)-----	21	0.04- 1.4	0.36- 0.47	0.36(31.5)
Manganese, total recoverable (mg/L)-----	20	0.015- 0.39	0.015-0.085	0.015(31.5)

## Ecological summary:

Prefers cool, fresh to slightly brackish waters with relatively small concentrations of sodium and sulfate; pH of 8.20 to 8.50 (alkalibiontic); sand substrates (0.05- to 2-mm diameter); and small streams (0.1 to 10 ft<sup>3</sup>/s) at lower elevations (less than 3,000 ft) in the study area. Tolerates some suspended sediment and turbidity and small concentrations of chloride. Summer (August and September) dominant.

## Distribution summary:

Widespread. Best population development in Logging Creek (station 28) and the downstream part of Rosebud Creek.



ECOTYPE: *NAVICULA TRIPUNCTATA* (O. F. MULL.) BORY

Biotype(s):

*N. tripunctata* (O. F. Mull.) Bory var. *tripunctata*

*N. tripunctata* var. *schizonemoides* (V. H.) Patr.

Reference:

Patrick and Reimer, 1966 (p. 513; pl. 49, fig. 3)

Herbarium slide number:

1-1-14

Mean percent relative abundance:

1.0

Percent occurrence:

42.2

Abundance-occurrence index:

41.2

Preferred percent occurrence:

2.4

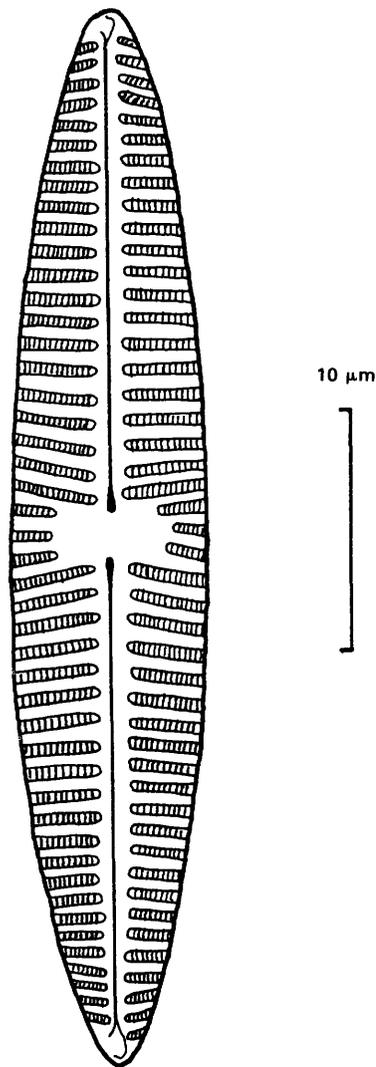
Maximum percent relative abundance:

32.6

Station number: 48

Date: June 1, 1979

Type of collection: E



Description:

Striae, 10-12 in 10  $\mu$ m. Length, 43.6  $\mu$ m. Width, 8.4  $\mu$ m. Distinguished from other species of *Navicula* by the obtuse ends, the large rectangular central area, and the almost parallel striae.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	116	239–6100	506– 868	662(21.6)
pH (units)	116	7.70– 8.72	8.21– 8.40	8.40(21.6)
Temperature ( $^{\circ}\text{C}$ )	118	1.0– 26.0	14.5– 19.0	19.0(21.6)
Turbidity (NTU)	110	0.5–3250	2.0– 7.5	2.0(21.6)
Oxygen, dissolved (mg/L)	83	7.02– 13.8	8.70– 9.45	8.70(21.6)
Biochemical oxygen demand (mg/L)	31	0.5– 3.6		1.4(4.9)
Hardness, total (mg/L $\text{CaCO}_3$ )	75	124–2040	239– 475	371(21.6)
Calcium, dissolved (mg/L)	75	27.4– 254	52.1– 79.6	68.0(21.6)
Magnesium, dissolved (mg/L)	75	13.5– 342	26.4– 67.0	48.9(21.6)
Sodium, dissolved (mg/L)	79	9.1– 995	12.8– 22.3	12.8(21.6)
Bicarbonate (mg/L)	86	15– 671	283– 447	359(21.6)
Carbonate (mg/L)	21	0.5– 24.0	6.7– 6.7	6.7(21.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	86	13– 557	232– 367	306(21.6)
Sulfate, dissolved (mg/L)	79	34–5450	41– 124	70(21.6)
Chloride, dissolved (mg/L)	79	0.4– 51.6	2.2– 3.0	2.4(21.6)
Fluoride, dissolved (mg/L)	78	0.1– 1.2	0.6– 1.2	0.6(21.6)
Dissolved solids, calculated (mg/L)	75	184–7680	425– 744	569(21.6)
Sediment, total suspended (mg/L)	108	0.4–8260	4.0– 18.0	4.0(21.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	67	0.01– 0.53	0.03– 0.07	0.04(21.6)
Nitrogen, total ammonia (mg/L as N)	63	0.01– 0.30	0.01– 0.03	0.01(21.6)
Phosphorus, total (mg/L as P)	88	0.010– 3.7	0.017–0.040	0.017(21.6)
Phosphorus, total ortho (mg/L as P)	89	0.001– 2.5	0.004–0.029	0.010(21.6)
Iron, total recoverable (mg/L)	58	0.02– 1.4	0.14– 0.33	0.14(21.6)
Manganese, total recoverable (mg/L)	54	0.005– 0.36	0.025–0.055	0.025(21.6)

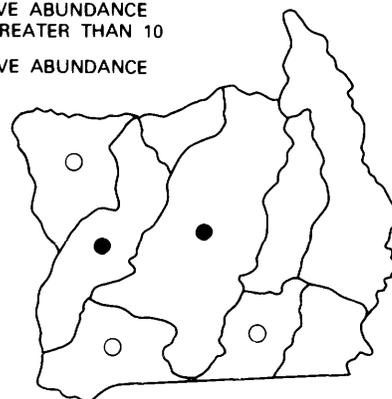
Ecological summary:

Prefers cool, fresh, calcium-magnesium bicarbonate waters with relatively small concentrations of sodium, sulfate, chloride, suspended sediment, and turbidity; pH of 8.20 to 8.40 (alkalibiontic); gravel substrates (greater than 0.2-cm diameter); and medium streams (0.1 to 100 ft<sup>3</sup>/s) at higher elevations (3,500 to 4,000 ft).

Distribution summary:

Distribution limited to relatively good-quality (little dissolved solids) waters in the study area, with best population development in Cow Creek near Fort Howe (station 19), Indian Creek (station 24), Rosebud Creek, and the Tongue River downstream from Hanging Woman Creek.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NAVICULA VIRIDULA* VAR. *AVENACEA* (Breb. ex Grun.) V. H.

Biotype(s):

*N. viridula* var. *avenacea* (Breb. ex Grun.) V. H.

Reference:

Patrick and Reimer, 1966 (p. 507; pl. 48, fig. 10)

Herbarium slide number:

1-3-16

Mean percent relative abundance:

2.8

Percent occurrence:

45.7

Abundance-occurrence index:

127.7

Preferred percent occurrence:

8.9

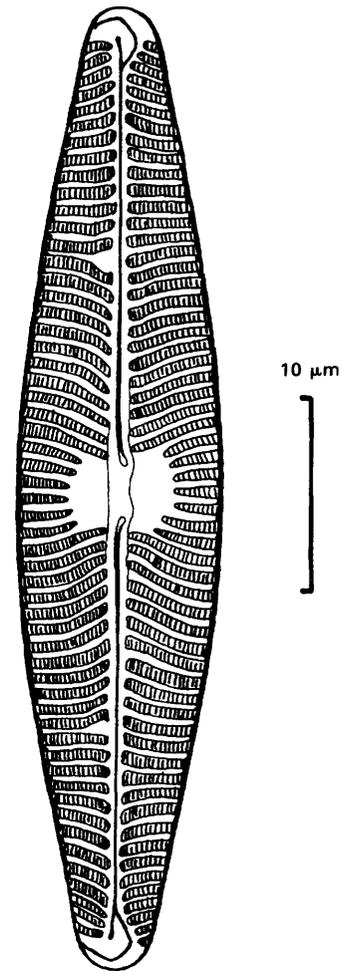
Maximum percent relative abundance:

49.3

Station number: 12

Date: June 10, 1978

Type of collection: E



Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Length, 47.8  $\mu\text{m}$ . Width, 10.4  $\mu\text{m}$ . A large, lanceolate *Navicula* with a large, rounded central area. Distinguished from *N. lanceolata* (Ag.) Kutz. and from other varieties of *N. viridula* in that the ends are not set off from the valve body.

## Water-quality profile:

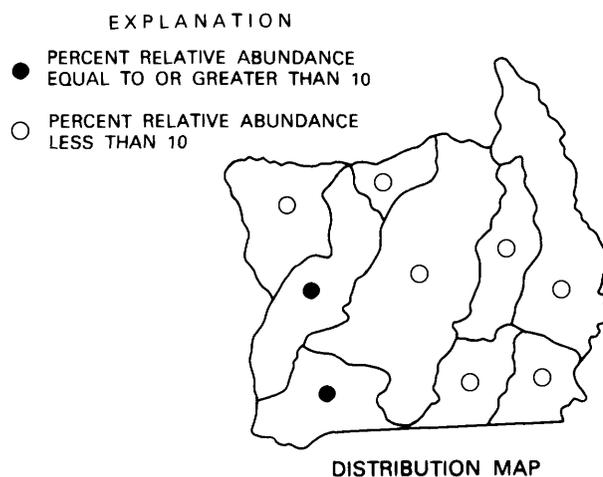
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	142	239–7030	782– 2550	1280(49.3)
pH (units)	142	7.50– 8.72	8.10– 8.42	8.42(49.3)
Temperature ( $^{\circ}\text{C}$ )	141	1.0– 30.5	1.7– 21.8	15.0(49.3)
Turbidity (NTU)	140	0.6–3250	1.7– 190	6.7(49.3)
Oxygen, dissolved (mg/L)	108	5.40– 19.0	8.10– 14.0	9.55(49.3)
Biochemical oxygen demand (mg/L)	43	0.5– 8.9	1.4– 3.5	1.4(32.2)
Hardness, total (mg/L $\text{CaCO}_3$ )	86	123–1430	379– 967	764(32.2)
Calcium, dissolved (mg/L)	86	16.0– 190	65.6– 121	107(32.2)
Magnesium, dissolved (mg/L)	86	13.5– 242	52.0– 161	121(32.2)
Sodium, dissolved (mg/L)	92	9.1–1470	17.2– 140	93.8(32.2)
Bicarbonate (mg/L)	94	15– 776	370– 636	473(32.2)
Carbonate (mg/L)	20	0.5– 29.0	1.0– 4.1	1.0(22.1)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	94	13– 636	310– 521	388(32.2)
Sulfate, dissolved (mg/L)	92	34–3400	124– 770	565(32.2)
Chloride, dissolved (mg/L)	92	0.4– 174	2.5– 14.0	2.9(32.2)
Fluoride, dissolved (mg/L)	90	0.04– 1.5	0.1– 1.1	0.4(32.2)
Dissolved solids, calculated (mg/L)	86	184–5800	673– 1780	1360(32.2)
Sediment, total suspended (mg/L)	131	0.2–8260	1.8– 413	9.6(49.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	77	0.01– 0.53	0.01– 0.34	0.32(29.1)
Nitrogen, total ammonia (mg/L as N)	86	0.01– 0.57	0.01– 0.07	0.04(29.1)
Phosphorus, total (mg/L as P)	100	0.010– 3.7	0.020–0.079	0.050(32.2)
Phosphorus, total ortho (mg/L as P)	105	0.001– 2.5	0.004–0.058	0.028(32.2)
Iron, total recoverable (mg/L)	63	0.02– 2.1	0.02– 0.75	0.60(32.2)
Manganese, total recoverable (mg/L)	56	0.005– 0.27	0.020– 0.17	0.17(32.2)

## Ecological summary:

Prefers fresh to slightly brackish waters with relatively small concentrations of sodium; gravel substrates (0.6– to 3–cm diameter); and medium streams (0.1 to 100  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft) in the study area. Eurythermal between 1 and 22  $^{\circ}\text{C}$ . Tolerates some suspended sediment and turbidity. Spring (April to June) dominant.

## Distribution summary:

Found throughout the study area. Best population development in the Rosebud Creek and upstream Tongue River drainages.



ECOTYPE: *NITZSCHIA ACICULARIS* W. SMITH

Biotype(s):

*N. acicularis* W. Smith var. *acicularis*

Reference:

Hustedt, 1930b (p. 423; fig. 821)

Herbarium slide number:

1-3-18

Mean percent relative abundance:

0.6

Percent occurrence:

47.6

Abundance-occurrence index:

30.9

Preferred percent occurrence:

0.8

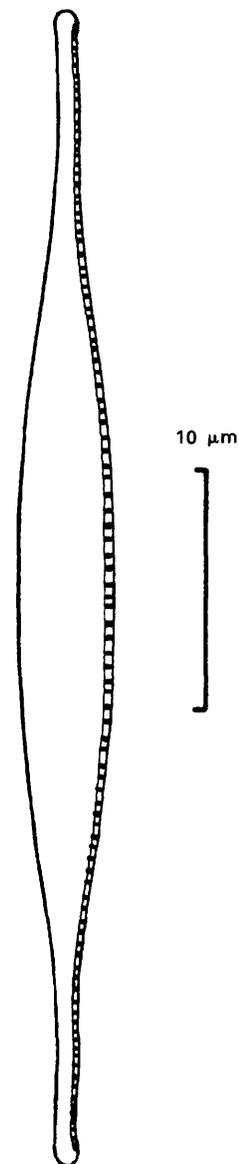
Maximum percent relative abundance:

29.3

Station number: 32

Date: October 29, 1979

Type of collection: E



Description:

Keel puncta 17-23 in 10  $\mu\text{m}$ . Length, 48.0  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . A very slender *Nitzschia* with long, protracted ends. Striae extremely fine, hardly if at all visible under most optical microscopes. Similar to *N. closterium*, except that the ends are straight and not curved.

Water-quality profile:

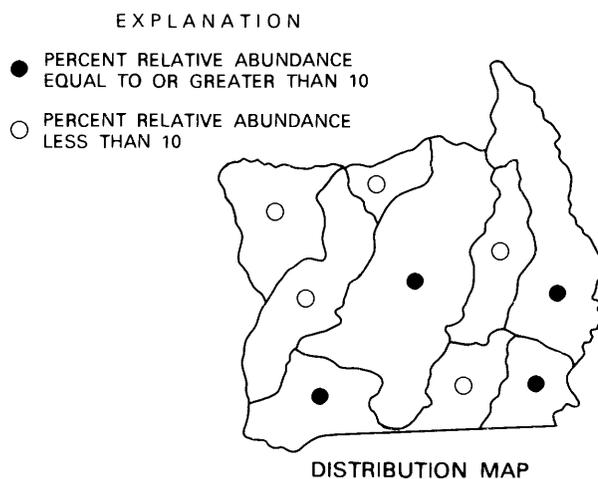
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	162	270– 8700	798– 2620	2620(29.3)
pH (units)	161	7.50– 8.80	8.21– 8.45	8.21(29.3)
Temperature ( $^{\circ}\text{C}$ )	163	1.3– 30.5	8.3– 10.5	10.5(29.3)
Turbidity (NTU)	157	0.5–11600	1.7– 23	23(29.3)
Oxygen, dissolved (mg/L)	119	4.52– 19.0	11.7– 11.7	11.7(10.9)
Biochemical oxygen demand (mg/L)	47	0.5– 4.9	1.8– 1.8	1.8(10.9)
Hardness, total (mg/L $\text{CaCO}_3$ )	91	92– 3320	359– 359	359(10.9)
Calcium, dissolved (mg/L)	91	16.0– 360	65.2– 65.2	65.2(10.9)
Magnesium, dissolved (mg/L)	91	5.0– 605	47.7– 47.7	47.7(10.9)
Sodium, dissolved (mg/L)	102	9.1– 1770	46.2– 46.2	46.2(10.9)
Bicarbonate (mg/L)	109	45– 913	273– 274	274(29.3)
Carbonate (mg/L)	25	0.5– 38.4	4.8– 4.8	4.8(10.9)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	109	39– 748	225– 232	225(29.3)
Sulfate, dissolved (mg/L)	102	34– 5450	211– 211	211(10.9)
Chloride, dissolved (mg/L)	102	1.2– 126	4.2– 4.2	4.2(10.9)
Fluoride, dissolved (mg/L)	99	0.1– 1.5	0.4– 0.4	0.4(10.9)
Dissolved solids, calculated (mg/L)	91	196– 7680	653– 653	653(10.9)
Sediment, total suspended (mg/L)	145	0.2–22600	0.9– 45.6	45.6(29.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	70	0.01– 0.80	0.02– 0.02	0.02(10.9)
Nitrogen, total ammonia (mg/L as N)	86	0.01– 0.21	0.01– 0.02	0.02(29.3)
Phosphorus, total (mg/L as P)	107	0.010– 0.60	0.010–0.020	0.020(29.3)
Phosphorus, total ortho (mg/L as P)	107	0.001– 0.38	0.010–0.010	0.010(29.3)
Iron, total recoverable (mg/L)	64	0.02– 1.1	0.05– 0.05	0.05(10.9)
Manganese, total recoverable (mg/L)	51	0.015– 0.41	0.019–0.019	0.019(10.9)

Ecological summary:

Prefers fresh to somewhat brackish waters; pH greater than 8.00; cold temperatures (8.0 to 10.5  $^{\circ}\text{C}$ ); sand substrates (0.05– to 2–mm diameter); and larger streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 2,500 ft). Fall (October and November) dominant. Tolerates considerable amounts of suspended sediment and turbidity, but does best at smaller concentrations.

Distribution summary:

Found throughout the study area. Best population development in the Little Powder River and the downstream part of the Powder River.



ECOTYPE: *NITZSCHIA AMPHIBIA* GRUN.

Biotype(s):

*N. amphibia* Grun. var. *amphibia*

Reference:

Hustedt, 1930b (p. 414; fig. 793)

Herbarium slide number:

1-3-19

Mean percent relative abundance:

0.3

Percent occurrence:

42.4

Abundance-occurrence index:

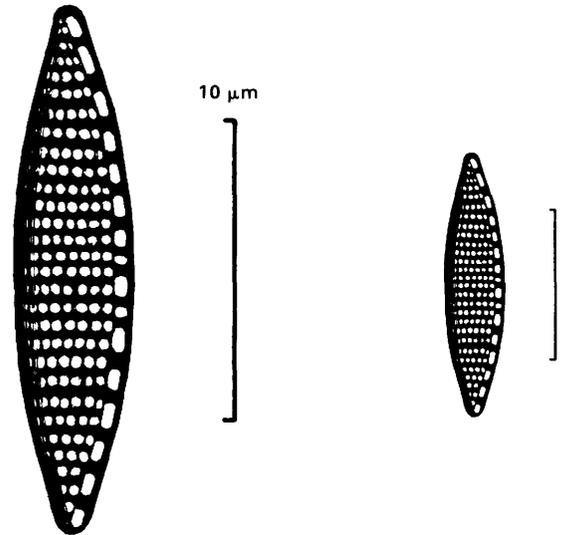
13.1

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

15.7



Station number: 4

Date: June 16, 1978

Type of collection: F

Description:

Striae, 17-18 in 10  $\mu\text{m}$ . Keel puncta, 9-10 in 10  $\mu\text{m}$ . Length, 17.5  $\mu\text{m}$ . Width, 3.8  $\mu\text{m}$ . A relatively small *Nitzschia* with coarse striae and keel puncta. Easily distinguished on this basis from the other species of *Nitzschia* in the study area.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	140	270– 6400	2410–2410	2410(15.7)
pH (units)	140	7.62– 8.80	8.52– 8.52	8.52(15.7)
Temperature ( $^{\circ}\text{C}$ )	139	1.3– 30.5	25.5– 25.5	25.5(15.7)
Turbidity (NTU)	139	0.5–11600	23– 23	23(15.7)
Oxygen, dissolved (mg/L)	105	0.80– 19.0	8.00– 8.00	8.00(15.7)
Biochemical oxygen demand (mg/L)	40	1.0– 8.3	-----	3.0(5.1)
Hardness, total (mg/L $\text{CaCO}_3$ )	87	92– 3320	-----	1230(5.1)
Calcium, dissolved (mg/L)	87	16.0– 330	-----	156(5.1)
Magnesium, dissolved (mg/L)	87	5.0– 605	-----	203(5.1)
Sodium, dissolved (mg/L)	96	9.1– 1230	-----	740(5.1)
Bicarbonate (mg/L)	96	45– 913	-----	661(5.1)
Carbonate (mg/L)	22	0.5– 38.4	-----	11.0(1.9)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	96	39– 748	-----	542(5.1)
Sulfate, dissolved (mg/L)	96	17– 4040	-----	2110(5.1)
Chloride, dissolved (mg/L)	96	0.4– 54.6	-----	10.9(5.1)
Fluoride, dissolved (mg/L)	95	0.1– 1.7	-----	0.4(5.1)
Dissolved solids, calculated (mg/L)	87	196– 6290	-----	3880(5.1)
Sediment, total suspended (mg/L)	129	0.4–22600	-----	27.6(6.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	67	0.01– 0.80	-----	0.20(2.8)
Nitrogen, total ammonia (mg/L as N)	91	0.01– 0.57	-----	0.02(6.4)
Phosphorus, total (mg/L as P)	101	0.010– 0.15	-----	0.090(6.4)
Phosphorus, total ortho (mg/L as P)	100	0.001– 0.080	-----	0.041(6.4)
Iron, total recoverable (mg/L)	63	0.02– 1.4	-----	1.1(2.2)
Manganese, total recoverable (mg/L)	53	0.010– 0.41	-----	0.23(2.2)

Ecological summary:

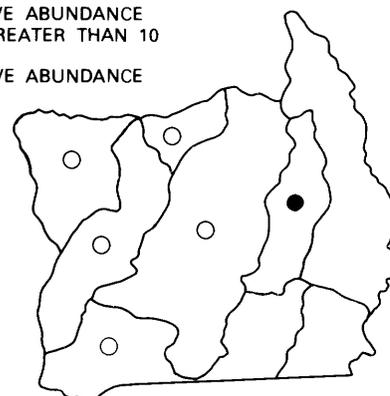
Prefers warm, brackish, sodium sulfate waters; pH greater than 8.00; fine to medium gravels (0.2– to 3–cm diameter); and larger streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 2,500 ft). Tolerates some suspended sediment and turbidity. Spring and early summer (May to July) dominant.

Distribution summary:

Distributed throughout the western part of study area. Best population development in Mizpah Creek.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NITZSCHIA CLOSTERIUM* (EHR.) W. SMITH

Biotype(s):

*N. closterium* (Ehr.) W. Smith var. *closterium*

Reference:

Hustedt, 1930b (p. 424; fig. 822)

Herbarium slide number:

1-4-7

Mean percent relative abundance:

1.5

Percent occurrence:

40.8

Abundance-occurrence index:

61.9

Preferred percent occurrence:

3.8

Maximum percent relative abundance:

52.3

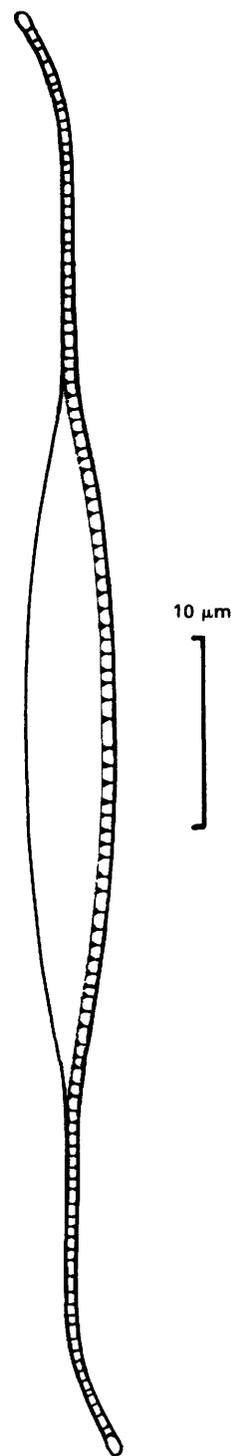
Station number: 8

Date: September 5, 1979

Type of collection: C

Description:

Keel puncta, 12-18 in 10  $\mu\text{m}$ . Length, 75.0  $\mu\text{m}$ . Width, 4.8  $\mu\text{m}$ . A seemingly transparent *Nitzschia* with extremely fine striae that are practically invisible under all but the best quality optical microscopes. Similar to *N. acicularis*, except that the ends are curved instead of straight. This taxon often has been called *N. longissima* var. *reversa* Grun. by American workers. *N. longissima* (Breb.) Ralfs is an extremely large and robust marine diatom. *N. closterium* is much smaller and finer in detail and apparently restricted to inland waters. Hustedt (1930b) writes that the ends of *N. closterium* can be bent either in the same direction or in opposite directions; the latter is the most common form in our collections. Distinguished from *N. reversa* W. Sm., which is not found in the study area, by the presence of a median gap in the row of keel puncta.



## Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	125	478-11000	1860- 8700	2930(52.3)
pH (units) -----	125	7.60- 8.73	8.12- 8.65	8.32(52.3)
Temperature ( $^{\circ}\text{C}$ ) -----	127	1.3- 30.5	3.3- 27.5	19.4(52.3)
Turbidity (NTU) -----	125	0.7-11600	3.3- 29	16(52.3)
Oxygen, dissolved (mg/L) -----	88	0.80- 19.0	5.65- 19.0	11.7(52.3)
Biochemical oxygen demand (mg/L) -----	26	1.5- 8.3	3.6- 4.9	3.6(35.0)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	67	92- 3490	243- 1400	1400(28.1)
Calcium, dissolved (mg/L) -----	67	16.0- 330	35.7- 190	190(28.1)
Magnesium, dissolved (mg/L)-----	67	5.0- 645	37.1- 226	226(28.1)
Sodium, dissolved (mg/L) -----	73	31.1- 1950	197- 1770	1770(40.6)
Bicarbonate (mg/L)-----	76	171- 913	449- 739	739(40.6)
Carbonate (mg/L) -----	19	0.5- 36.0	19.0- 29.0	29.0(16.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	76	146- 748	368- 606	606(40.6)
Sulfate, dissolved (mg/L) -----	73	138- 6900	507- 5290	5290(40.6)
Chloride, dissolved (mg/L) -----	73	2.2- 174	6.8- 27.8	24.4(40.6)
Fluoride, dissolved (mg/L) -----	71	0.04- 1.7	0.04- 1.5	0.4(40.6)
Dissolved solids, calculated (mg/L) -----	67	416-10400	1630- 5800	5300(28.1)
Sediment, total suspended (mg/L) -----	115	0.2-22600	4.0- 45.6	40.1(52.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	48	0.01- 0.71	0.03- 0.10	0.04(40.6)
Nitrogen, total ammonia (mg/L as N) -----	81	0.01- 0.57	0.01- 0.21	0.17(40.6)
Phosphorus, total (mg/L as P)-----	89	0.010- 3.7	0.011- 0.11	0.080(40.6)
Phosphorus, total ortho (mg/L as P)-----	87	0.001- 2.5	0.004-0.024	0.012(40.6)
Iron, total recoverable (mg/L)-----	35	0.04- 0.75	0.23- 0.75	0.23(40.6)
Manganese, total recoverable (mg/L)-----	30	0.020- 0.41	0.073- 0.37	0.11(16.6)

## Ecological summary:

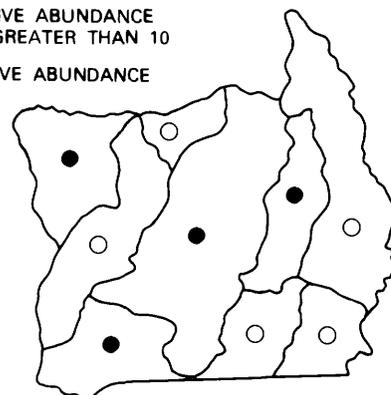
Prefers brackish, sodium sulfate waters; fine to medium gravels (0.2- to 3-cm diameter); and smaller streams (0 to 10 ft<sup>3</sup>/s) at less than 4,000 ft elevation. Tolerates some suspended sediment and turbidity. Eurythermal over the range 3 to 28 $^{\circ}\text{C}$ . Late summer and fall (August to November) dominant.

## Distribution summary:

Found throughout the study area. Best population development in Squirrel Creek near Decker (station 8).

### EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NITZSCHIA COMMUNIS* RABH.

Biotype(s):

*N. bergii* A. Cl. var. *bergii*  
\**N. communis* Rabh. var. *communis*

Reference:

Hustedt, 1930b (p. 417; fig. 798)

Herbarium slide number:

1-3-20

Mean percent relative abundance:

0.6

Percent occurrence:

53.0

Abundance-occurrence index:

31.4

Preferred percent occurrence:

0.3

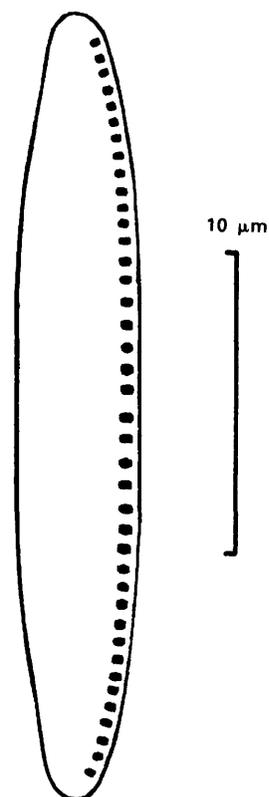
Maximum percent relative abundance:

13.7

Station number: 6

Date: September 6, 1978

Type of collection: E



Description:

Keel puncta, 14-17 in 10  $\mu\text{m}$ . Length, 26.3  $\mu\text{m}$ . Width, 4.2  $\mu\text{m}$ . A small, transparent *Nitzschia* with blunt ends. Striae are so fine as to be practically invisible under most optical microscopes. Distinguished from *N. palea* and other transparent *Nitzschias* by the broadly rounded rather than pointed or protracted ends.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	164	438-11000	1250- 1250	1250(14.2)
pH (units)	164	7.41- 8.80	8.44- 8.44	8.44(14.2)
Temperature ( $^{\circ}\text{C}$ )	165	1.3- 30.5		19.5(7.8)
Turbidity (NTU)	162	0.5- 4200	67- 67	67(14.2)
Oxygen, dissolved (mg/L)	122	0.80- 19.0	9.52- 9.52	9.52(14.2)
Biochemical oxygen demand (mg/L)	43	0.5- 8.9		3.3(5.2)
Hardness, total (mg/L $\text{CaCO}_3$ )	97	123- 3490		833(7.6)
Calcium, dissolved (mg/L)	97	16.0- 328		96.8(7.6)
Magnesium, dissolved (mg/L)	97	18.3- 645		144(7.6)
Sodium, dissolved (mg/L)	106	11.5- 1950		352(7.6)
Bicarbonate (mg/L)	110	148- 913		630(7.6)
Carbonate (mg/L)	27	0.5- 38.4		0.5(7.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	110	133- 748		518(7.6)
Sulfate, dissolved (mg/L)	106	38- 6900		1050(7.6)
Chloride, dissolved (mg/L)	106	0.4- 126		3.1(7.6)
Fluoride, dissolved (mg/L)	103	0.04- 1.7		0.6(7.6)
Dissolved solids, calculated (mg/L)	97	398-10400		2270(7.6)
Sediment, total suspended (mg/L)	150	0.2- 8260	127- 127	127(14.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	80	0.01- 0.71	0.02- 0.02	0.02(14.2)
Nitrogen, total ammonia (mg/L as N)	100	0.01- 0.57	0.03- 0.03	0.03(14.2)
Phosphorus, total (mg/L as P)	116	0.010- 3.7	0.050-0.050	0.050(14.2)
Phosphorus, total ortho (mg/L as P)	116	0.001- 2.5	0.052-0.052	0.052(14.2)
Iron, total recoverable (mg/L)	64	0.02- 2.1		0.36(7.8)
Manganese, total recoverable (mg/L)	56	0.005- 0.41		0.10(7.8)

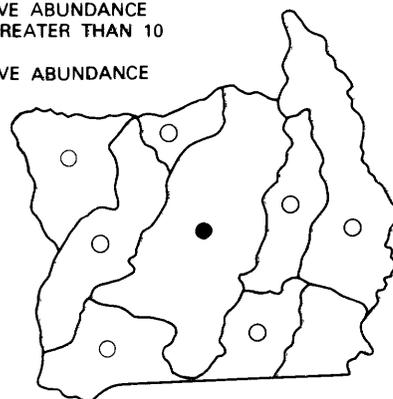
Ecological summary:

Prefers somewhat brackish, sodium sulfate waters; gravel bottoms (0.2- to 3-cm diameter); and lower elevations (less than 3,000 ft). Indifferent to stream size and season of the year. Tolerates considerable amounts of suspended sediment and turbidity.

Distribution summary:

Widespread. Best population development in Pumpkin Creek.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NITZSCHIA DISSIPATA* (KUTZ.) GRUN.

Biotype(s):

*N. dissipata* (Kutz.) Grun. var. *dissipata*

Reference:

Hustedt, 1930b (p. 412; fig. 789)

Herbarium slide number:

1-4-1

Mean percent relative abundance:

2.8

Percent occurrence:

74.1

Abundance-occurrence index:

210.3

Preferred percent occurrence:

9.5

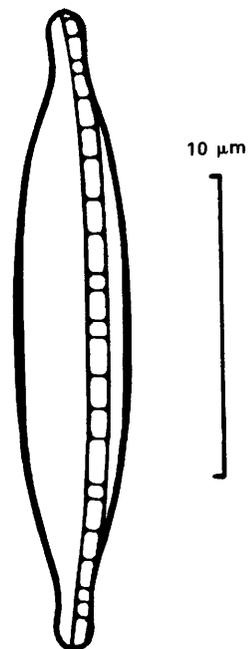
Maximum percent relative abundance:

23.4

Station number: 24

Date: July 25, 1978

Type of collection: E



Description:

Keel puncta, 9-11 in 10  $\mu\text{m}$ . Length, 21.3  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . A small transparent *Nitzschia* with coarse keel puncta and protracted ends. Keel slightly eccentric. Striae extremely fine and invisible under most optical microscopes. The only member of the Dissipatae group found in the study area.

Water-quality profile:

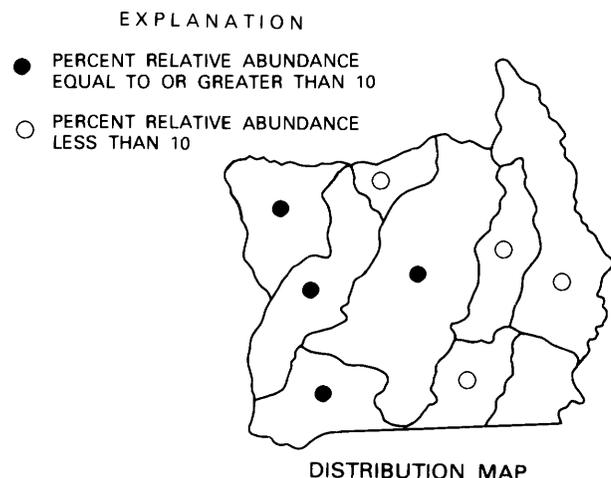
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	219	239–6100	362– 4350	690(23.4)
pH (units)	218	7.50– 8.73	8.19– 8.50	8.19(23.4)
Temperature ( $^{\circ}\text{C}$ )	218	1.0– 30.5	4.3– 23.5	19.5(23.4)
Turbidity (NTU)	213	0.5–3250	1.6– 190	11(23.4)
Oxygen, dissolved (mg/L)	153	5.40– 15.0	7.70– 14.0	7.70(23.4)
Biochemical oxygen demand (mg/L)	63	0.5– 8.9	1.8– 3.5	2.2(23.4)
Hardness, total (mg/L $\text{CaCO}_3$ )	133	123–2040	181– 1430	375(23.4)
Calcium, dissolved (mg/L)	133	16.0– 254	38.6– 174	69.6(23.4)
Magnesium, dissolved (mg/L)	133	13.5– 346	20.6– 242	48.9(23.4)
Sodium, dissolved (mg/L)	139	9.1– 995	11.5– 662	12.8(23.4)
Bicarbonate (mg/L)	148	15– 798	15– 586	392(23.4)
Carbonate (mg/L)	33	0.5– 24.0	2.0– 8.4	2.0(22.0)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	148	13– 654	13– 481	321(23.4)
Sulfate, dissolved (mg/L)	139	34–5450	67– 2390	69(23.4)
Chloride, dissolved (mg/L)	139	0.4– 174	2.2– 12.6	2.4(23.4)
Fluoride, dissolved (mg/L)	135	0.1– 1.7	0.2– 1.2	0.6(23.4)
Dissolved solids, calculated (mg/L)	133	184–7680	184– 4020	596(23.4)
Sediment, total suspended (mg/L)	205	0.2–8260	0.9– 413	67.4(23.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	114	0.01– 0.66	0.01– 0.19	0.08(23.4)
Nitrogen, total ammonia (mg/L as N)	131	0.01– 0.30	0.01– 0.05	0.02(23.4)
Phosphorus, total (mg/L as P)	162	0.010– 3.7	0.010– 0.13	0.064(23.4)
Phosphorus, total ortho (mg/L as P)	163	0.001– 2.5	0.002–0.079	0.023(23.4)
Iron, total recoverable (mg/L)	86	0.02– 2.1	0.05– 1.4	0.59(23.4)
Manganese, total recoverable (mg/L)	80	0.005– 0.39	0.019– 0.15	0.095(23.4)

Ecological summary:

Prefers fresh to brackish, calcium magnesium bicarbonate waters; fine to medium gravels (0.2– to 3–cm diameter); and larger streams (greater than 10  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft). Eurythermal over a range of 4 to 24  $^{\circ}\text{C}$ . Tolerates large amounts of suspended sediment and turbidity. Summer and fall (June to October) dominant.

Distribution summary:

Widespread. Best population development in the western part of the study area.



ECOTYPE: *NITZSCHIA FILIFORMIS* (W. SM.) HUST.

Biotype(s):

*N. filiformis* (W. Sm.) Hust. var. *filiformis*

Reference:

Hustedt, 1930b (p. 422; fig. 818)

Herbarium slide number:

1-4-2

Mean percent relative abundance:

0.8

Percent occurrence:

33.2

Abundance-occurrence index:

27.1

Preferred percent occurrence:

1.9

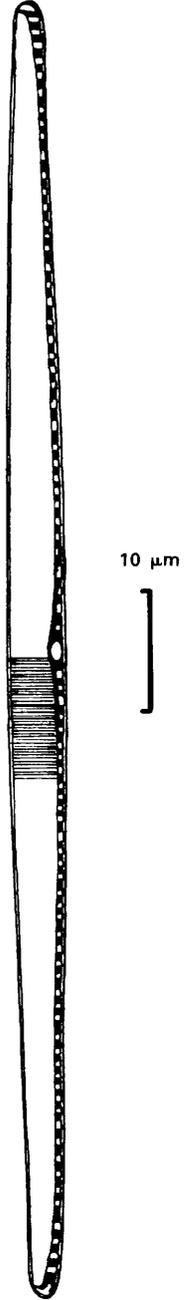
Maximum percent relative abundance:

29.1

Station number: 8

Date: November 1, 1979

Type of collection: C



Description:

Striae, 35-37 in 10  $\mu\text{m}$ . Keel puncta, 8-10 in 10  $\mu\text{m}$ . Length, 107.5  $\mu\text{m}$ . Width, 5.0  $\mu\text{m}$ . A long, slender *Nitzschia* with very fine striae and ends that are not set off from the body of the valve. Distinguished from *N. obtusa* by the finer striae, smaller size, and narrower valve. Distinguished from *N. ignorata* Krasske by being much less sigmoid in outline.

## Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	102	540–7030	540– 4800	2150(29.1)
pH (units)	102	7.65– 8.73	8.27– 8.59	8.27(29.1)
Temperature ( $^{\circ}\text{C}$ )	102	1.3– 30.5	2.8– 30.2	2.8(29.1)
Turbidity (NTU)	100	0.8–1500	5.1– 67	14(29.1)
Oxygen, dissolved (mg/L)	75	5.40– 19.0	9.52– 13.7	13.7(29.1)
Biochemical oxygen demand (mg/L)	31	0.5– 8.3	2.8– 2.8	2.8(29.1)
Hardness, total (mg/L $\text{CaCO}_3$ )	53	123–1610	273– 868	273(15.2)
Calcium, dissolved (mg/L)	53	16.0– 222	57.6– 82.6	57.6(15.2)
Magnesium, dissolved (mg/L)	53	18.3– 256	31.4– 160	31.4(15.2)
Sodium, dissolved (mg/L)	56	13.7–1470	19.0– 937	19.0(15.2)
Bicarbonate (mg/L)	59	45– 913	226– 495	226(15.2)
Carbonate (mg/L)	17	0.5– 36.0	8.2– 22.0	8.2(15.2)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	59	39– 748	199– 442	199(15.2)
Sulfate, dissolved (mg/L)	56	77–3400	102– 2360	102(15.2)
Chloride, dissolved (mg/L)	56	1.2– 126	3.1– 28.0	3.1(15.2)
Fluoride, dissolved (mg/L)	55	0.1– 1.5	0.3– 0.4	0.3(15.2)
Dissolved solids, calculated (mg/L)	53	448–5800	448– 4090	448(15.2)
Sediment, total suspended (mg/L)	94	0.2– 741	8.6– 127	21.6(29.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	41	0.01– 0.66	0.01– 0.07	0.07(29.1)
Nitrogen, total ammonia (mg/L as N)	62	0.01– 0.22	0.01– 0.03	0.03(29.1)
Phosphorus, total (mg/L as P)	72	0.010– 0.49	0.030–0.057	0.030(29.1)
Phosphorus, total ortho (mg/L as P)	70	0.001– 0.31	0.022–0.052	0.022(29.1)
Iron, total recoverable (mg/L)	29	0.04– 2.1	-----	0.36(7.5)
Manganese, total recoverable (mg/L)	27	0.015– 0.27	-----	0.10(7.5)

## Ecological summary:

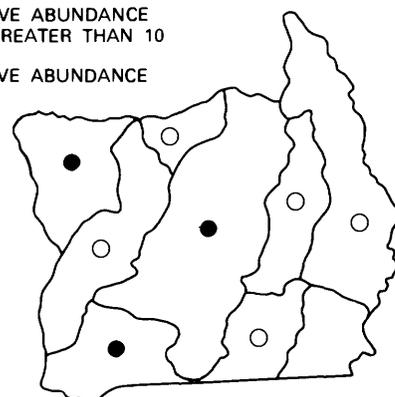
Prefers fresh to brackish waters; coarse sand to fine gravel substrates (0.03– to 1–cm diameter); and medium streams (0.1 to 100  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft). Tolerates some suspended sediment and turbidity. Fall and winter (October and March) dominant.

## Distribution summary:

Widespread. Best population development in Armells Creek and certain tributaries of the Tongue River.

### EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NITZSCHIA FRUSTULUM* (KUTZ.) GRUN.

Biotype(s):

- N. frustulum* (Kutz.) Grun. var. *frustulum*
- <sup>1</sup>*N. frustulum* var. *perminuta* Grun.
- <sup>2</sup>*N. frustulum* var. *perpusilla* (Rabh.) Grun.
- N. frustulum* var. *subsalina* Hust.

Reference:

<sup>1</sup>Hustedt, 1930b (p. 415); <sup>2</sup>Hustedt, 1930b (p. 415)

Herbarium slide number:

<sup>1</sup>1-4-3; <sup>2</sup>1-4-4

Mean percent relative abundance:

9.1

Percent occurrence:

93.0

Abundance-occurrence index:

844.2

Preferred percent occurrence:

31.1

Maximum percent relative abundance:

69.7

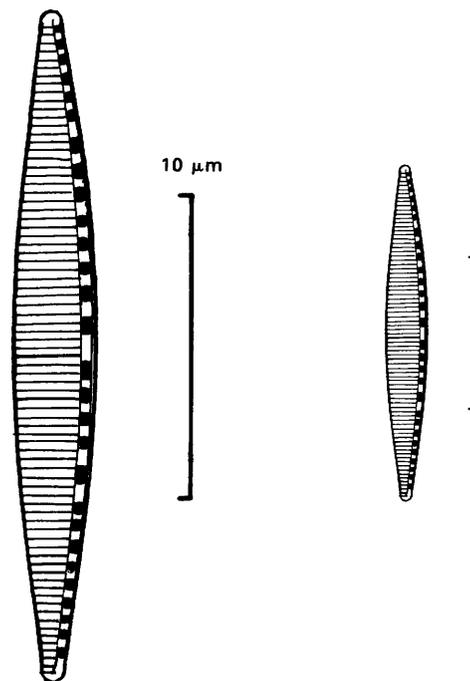
Station number: 6

Date: July 31, 1978

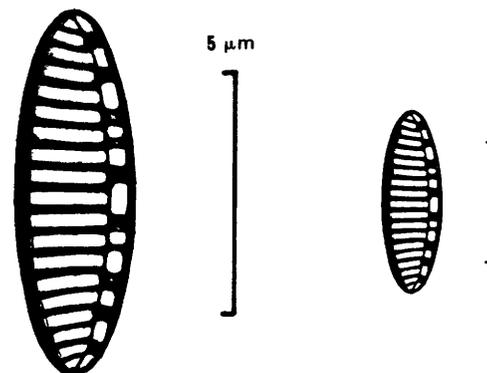
Type of collection: E

Description:

<sup>1</sup>Striae, 28-32 in 10  $\mu\text{m}$ . Keel puncta, 11-14 in 10  $\mu\text{m}$ . Length, 22.3  $\mu\text{m}$ . Width, 3.0  $\mu\text{m}$ . <sup>2</sup>Striae, 24-26 in 10  $\mu\text{m}$ . Keel puncta, 7-8 in 10  $\mu\text{m}$ . Length, 7.6  $\mu\text{m}$ . Width, 2.6  $\mu\text{m}$ . The *Nitzschia frustulum* complex is the most taxonomically perplexing ecotype in the southern Fort Union coal region. The two most common and morphologically distinct forms are illustrated and described. Intermediate between the nominate variety and variety *perpusilla* is a seemingly infinite number of variations on the *Nitzschia frustulum* theme, many of them often occurring together in a single collection. The median gap in each row of keel puncta seems to be a common denominator of all varieties. This complex needs a rigorous taxonomic analysis.



*N. frustulum* var. *perminuta*



*N. frustulum* var. *perpusilla*

Water-quality profile:

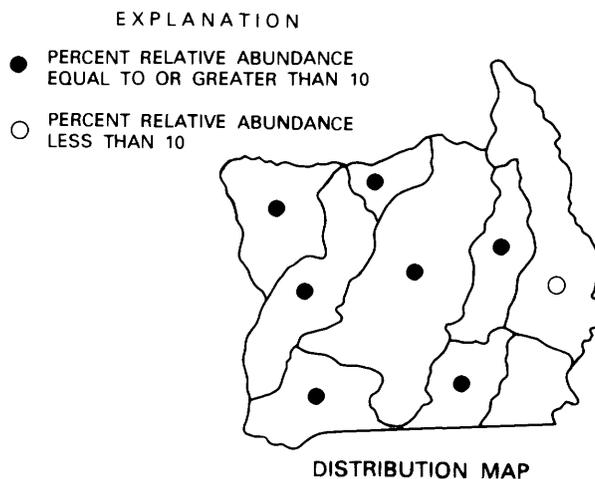
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	289	239-11000	480- 7030	1880(69.7)
pH (units)-----	289	7.41- 8.80	7.41- 8.73	8.41(69.7)
Temperature ( $^{\circ}\text{C}$ ) -----	289	1.0- 30.5	1.7- 30.2	25.5(69.7)
Turbidity (NTU) -----	282	0.5-11600	0.7-11600	22(69.7)
Oxygen, dissolved (mg/L) -----	209	0.80- 19.0	0.80- 14.3	0.80(69.7)
Biochemical oxygen demand (mg/L)-----	78	0.5- 8.9	1.5- 8.9	6.0(68.8)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	172	92- 3490	92- 3320	339(69.7)
Calcium, dissolved (mg/L)-----	172	16.0- 360	28.8- 330	65.0(69.7)
Magnesium, dissolved (mg/L) -----	172	5.0- 645	5.0- 605	42.9(69.7)
Sodium, dissolved (mg/L)-----	185	9.1- 1950	15.8- 1470	350(69.7)
Bicarbonate (mg/L) -----	194	15- 913	45- 816	354(69.7)
Carbonate (mg/L)-----	47	0.5- 38.4	0.5- 36.0	12.0(69.7)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	194	13- 748	39- 669	310(69.7)
Sulfate, dissolved (mg/L)-----	185	17- 6900	17- 5450	782(69.7)
Chloride, dissolved (mg/L)-----	185	0.4- 174	1.2- 54.6	5.9(69.7)
Fluoride, dissolved (mg/L)-----	180	0.04- 1.7	0.2- 1.5	0.4(69.7)
Dissolved solids, calculated (mg/L)-----	172	184-10400	389- 7680	1610(69.7)
Sediment, total suspended (mg/L)-----	260	0.2-22600	0.9-22600	25.8(69.7)
Nitrogen, total $\text{NO}_2+\text{NO}_3$ (mg/L as N) -----	135	0.01- 0.80	0.01- 0.64	0.43(64.2)
Nitrogen, total ammonia (mg/L as N)-----	167	0.01- 0.57	0.01- 0.57	0.19(64.2)
Phosphorus, total (mg/L as P) -----	200	0.010- 3.7	0.010- 3.7	3.7(64.2)
Phosphorus, total ortho (mg/L as P) -----	201	0.001- 2.5	0.001- 2.5	2.5(64.2)
Iron, total recoverable (mg/L) -----	116	0.02- 2.1	0.04- 1.4	0.75(51.4)
Manganese, total recoverable (mg/L) -----	101	0.005- 0.41	0.010- 0.41	0.086(51.4)

Ecological summary:

Very broad ecological amplitude. Tolerates large amounts of suspended sediment and turbidity but does best at smaller concentrations. Does well on coarse sand particles or larger (greater than 0.3-mm diameter). Present in abundance in all size streams, at all elevations, and during all seasons. The several biotypes in this ecotype may represent several narrower and therefore more useful ecological amplitudes; however, great care and discipline are required to distinguish between them in most collections from the study area.

Distribution summary:

Present and abundant in all hydrologic units except the Little Powder and Lower Powder. This is the most common diatom ecotype in the southern Fort Union coal region.



ECOTYPE: *NITZSCHIA LINEARIS* W. SMITH

Biotype(s):

*N. linearis* W. Smith var. *linearis*

Reference:

Hustedt, 1930b (p. 409; fig. 784)

Herbarium slide number:

1-4-6

Mean percent relative abundance:

0.5

Percent occurrence:

49.2

Abundance-occurrence index:

22.3

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

11.0

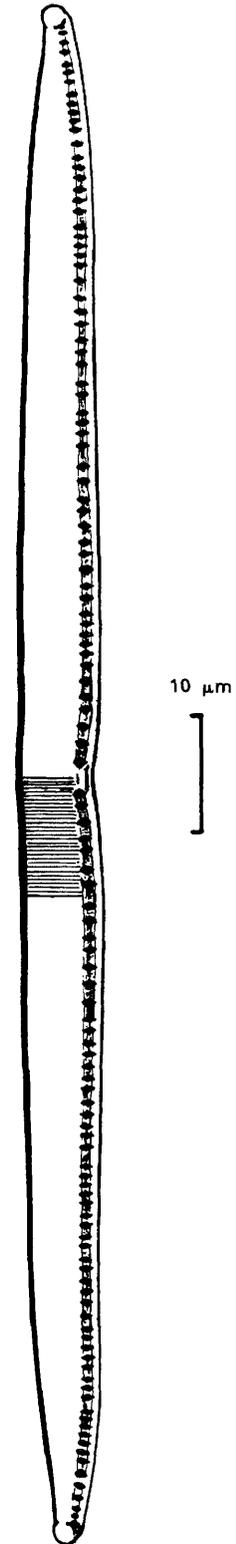
Station number: 1

Date: May 19, 1979

Type of collection: E

Description:

Striae, 28-30 in 10  $\mu\text{m}$ . Keel puncta, 8-13 in 10  $\mu\text{m}$ . Length, 128.0  $\mu\text{m}$ . Width, 6.5  $\mu\text{m}$ . A long, slender, parallel-sided *Nitzschia* with very fine striae and a shallow notch on one margin at midvalve. It does not closely resemble any of the other common *Nitzschia* species in the study area. Distinguished from *N. intermedia* Hantzsch, which is not common in the study area, by the central notch and much finer striae.



Water-quality profile:

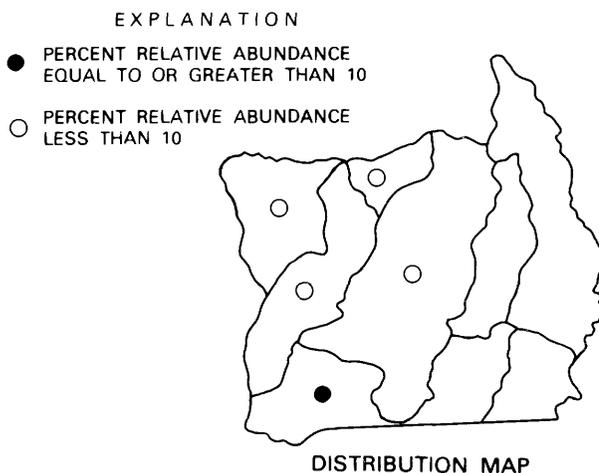
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	148	239–5760	1300– 1300	1300(11.0)
pH (units)	148	7.50– 8.64	8.20– 8.20	8.20(11.0)
Temperature ( $^{\circ}\text{C}$ )	148	1.7– 26.0	15.8– 15.8	15.8(11.0)
Turbidity (NTU)	143	0.5– 225	7.0– 7.0	7.0(11.0)
Oxygen, dissolved (mg/L)	112	4.52– 14.0	9.85– 9.85	9.85(11.0)
Biochemical oxygen demand (mg/L)	46	0.5– 8.9	2.3– 2.3	2.3(11.0)
Hardness, total (mg/L $\text{CaCO}_3$ )	94	145–2880	507– 507	507(11.0)
Calcium, dissolved (mg/L)	94	33.2– 360	86.4– 86.4	86.4(11.0)
Magnesium, dissolved (mg/L)	94	15.1– 482	71.0– 71.0	71.0(11.0)
Sodium, dissolved (mg/L)	102	9.5– 740	126– 126	126(11.0)
Bicarbonate (mg/L)	106	22– 816	548– 548	548(11.0)
Carbonate (mg/L)	26	0.5– 28.0	-----	1.0(5.0)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	106	124– 669	449– 449	449(11.0)
Sulfate, dissolved (mg/L)	102	38–3530	304– 304	304(11.0)
Chloride, dissolved (mg/L)	102	0.4– 51.6	4.0– 4.0	4.0(11.0)
Fluoride, dissolved (mg/L)	100	0.1– 1.7	1.1– 1.1	1.1(11.0)
Dissolved solids, calculated (mg/L)	94	254–5500	1140– 1140	1140(11.0)
Sediment, total suspended (mg/L)	136	0.2– 413	12.6– 12.6	12.6(11.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	74	0.01– 0.71	0.01– 0.01	0.01(11.0)
Nitrogen, total ammonia (mg/L as N)	72	0.01– 0.17	0.01– 0.01	0.01(11.0)
Phosphorus, total (mg/L as P)	96	0.010– 0.20	0.030–0.030	0.030(11.0)
Phosphorus, total ortho (mg/L as P)	101	0.001– 0.11	0.013–0.013	0.013(11.0)
Iron, total recoverable (mg/L)	71	0.02– 1.1	0.02– 0.02	0.02(11.0)
Manganese, total recoverable (mg/L)	61	0.005– 0.41	0.025–0.025	0.025(11.0)

Ecological summary:

Prefers cool, slightly brackish waters; relatively small amounts of suspended sediment and chloride; coarse sand substrates (0.3– to 2–mm diameter); and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 3,500 ft) in the study area. Spring (March to May) dominant.

Distribution summary:

Found in all hydrologic units except those representing the Powder River drainage. Seldom occurs in abundance. Best population development in the East Fork of Hanging Woman Creek.



ECOTYPE: *NITZSCHIA MICROCEPHALA* GRUN.

Biotype(s):

*N. microcephala* Grun. var. *microcephala*

Reference:

Hustedt, 1930b (p. 414; fig. 791)

Herbarium slide number:

1-4-8

Mean percent relative abundance:

1.0

Percent occurrence:

37.6

Abundance-occurrence index:

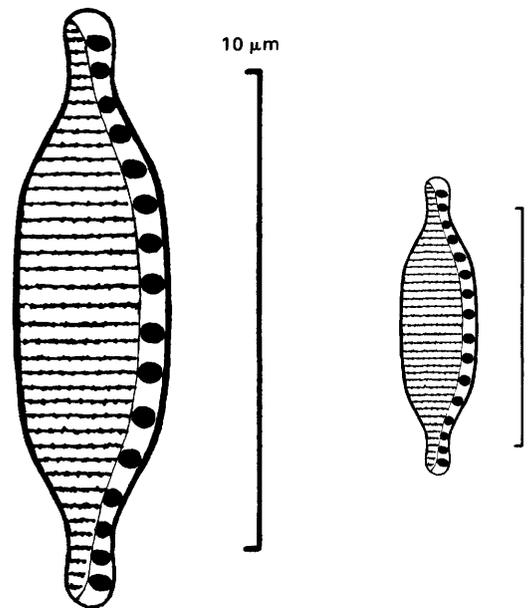
38.4

Preferred percent occurrence:

2.4

Maximum percent relative abundance:

40.0



Station number: 11

Date: September 21, 1979

Type of collection: E

Description:

Striae, 33-35 in 10 µm. Keel puncta, 12-13 in 10 µm. Length, 12.4 µm. Width, 3.6 µm. A very small *Nitzschia* with protracted and somewhat capitate ends. Similar in outline to *Cymbella microcephala*.

## Water-quality profile:

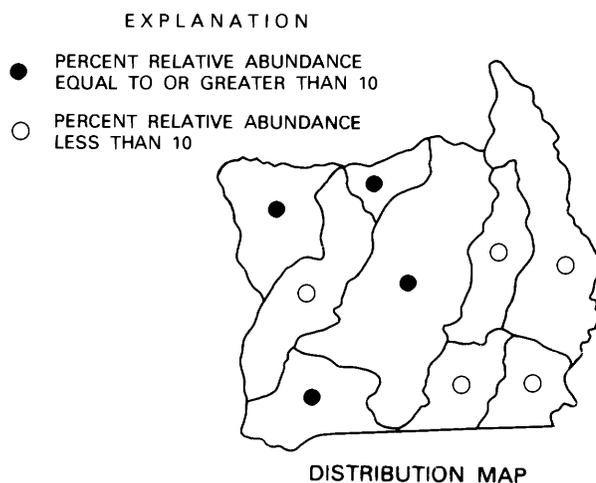
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	130	506–11000	2670– 4890	4300(40.0)
pH (units)	130	7.62– 8.80	7.90– 8.70	8.70(40.0)
Temperature ( $^{\circ}\text{C}$ )	129	1.3– 30.5	3.5– 24.4	24.3(40.0)
Turbidity (NTU)	129	0.5– 435	0.7– 14	1.5(40.0)
Oxygen, dissolved (mg/L)	96	0.80– 19.0	8.00– 14.8	14.8(40.0)
Biochemical oxygen demand (mg/L)	30	1.2– 8.3	1.6– 2.7	2.7(40.0)
Hardness, total (mg/L $\text{CaCO}_3$ )	86	123– 3490	441– 1040	808(22.6)
Calcium, dissolved (mg/L)	86	16.0– 330	54.3– 120	96.8(22.6)
Magnesium, dissolved (mg/L)	86	20.0– 645	73.8– 179	137(22.6)
Sodium, dissolved (mg/L)	93	19.5– 1950	352– 855	855(25.2)
Bicarbonate (mg/L)	93	198– 913	449– 755	755(25.2)
Carbonate (mg/L)	21	0.5– 38.4	0.5– 14.0	14.0(22.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	93	162– 748	368– 619	619(25.2)
Sulfate, dissolved (mg/L)	93	41– 6900	1050– 1920	1920(25.2)
Chloride, dissolved (mg/L)	93	0.4– 174	3.1– 43.1	17.2(25.2)
Fluoride, dissolved (mg/L)	89	0.04– 1.7	0.6– 1.7	0.6(25.2)
Dissolved solids, calculated (mg/L)	86	425–10400	2270– 2880	2510(22.6)
Sediment, total suspended (mg/L)	121	0.2– 893	1.0– 46.4	1.4(40.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	53	0.01– 0.80	0.11– 0.47	0.11(25.2)
Nitrogen, total ammonia (mg/L as N)	81	0.01– 0.57	0.01– 0.07	0.07(40.0)
Phosphorus, total (mg/L as P)	88	0.010– 0.62	0.010–0.050	0.010(40.0)
Phosphorus, total ortho (mg/L as P)	85	0.001– 0.52	0.006–0.016	0.010(25.2)
Iron, total recoverable (mg/L)	51	0.02– 1.1	0.15– 0.34	0.34(25.2)
Manganese, total recoverable (mg/L)	45	0.005– 0.41	0.020– 0.10	0.060(25.2)

## Ecological summary:

Prefers brackish, sodium sulfate waters; relatively large concentrations of inorganic nitrogen; fine to medium gravels (0.2– to 3–cm diameter); and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) below 4,000 ft in the study area. Eurythermal between 3 and 25  $^{\circ}\text{C}$ . Tolerates some suspended sediment, turbidity, and chloride. Summer and fall (July to October) dominant.

## Distribution summary:

Found throughout the study area. Best population development in Armells Creek near Forsyth (station 11).



ECOTYPE: *NITZSCHIA OBTUSA* W. SMITH

Biotype(s):

\**N. obtusa* W. Smith var. *obtusa*  
*N. obtusa* var. *scalpelliformis* Grun.

Reference:

Hustedt, 1930b (p. 422; fig. 817 a-c)

Herbarium slide number:

1-2-11

Mean percent relative abundance:

0.4

Percent occurrence:

7.0

Abundance-occurrence index:

2.7

Preferred percent occurrence:

1.6

Maximum percent relative abundance:

39.6

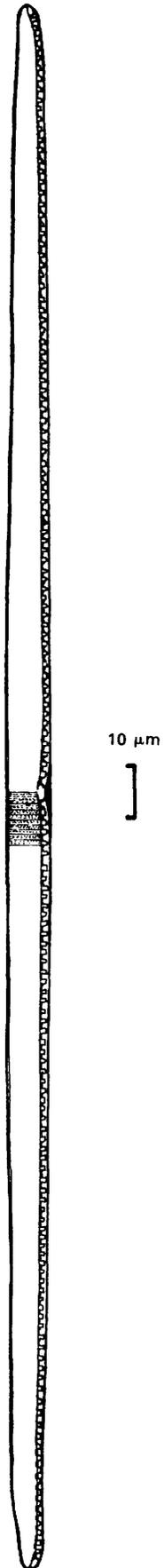
Station number: 30

Date: September 30, 1979

Type of collection: E

Description:

Striae, 30 in 10  $\mu\text{m}$ . Keel puncta, 5-6 in 10  $\mu\text{m}$ . Length, 293.0  $\mu\text{m}$ . Width, 7.6  $\mu\text{m}$ . An extremely large *Nitzschia* and one of the longest diatoms in the study area. Very similar in appearance to *N. filiformis* but much larger. Hustedt (1930b) gives the size range for *N. obtusa* var. *obtusa* as 120 to 350  $\mu\text{m}$ , whereas *N. filiformis* var. *filiformis* is listed as 20 to 100  $\mu\text{m}$  long.



Water-quality profile:

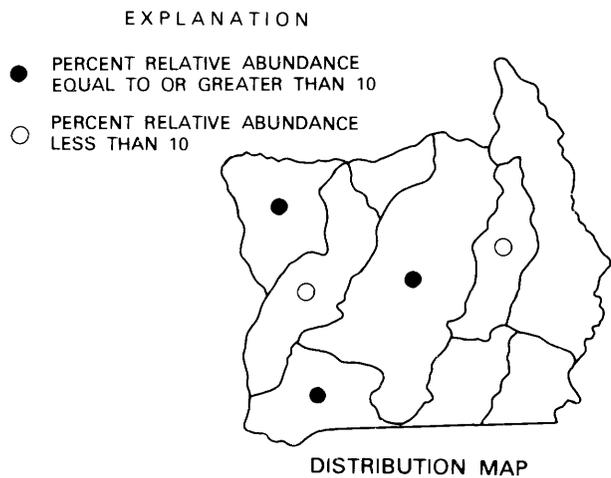
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	22	478– 6400	1020– 6400	6400(39.6)
pH (units)	22	7.60– 8.73	7.90– 8.55	8.22(39.6)
Temperature ( $^{\circ}\text{C}$ )	22	1.3– 29.2	3.5– 23.8	15.8(39.6)
Turbidity (NTU)	22	0.7–11600	0.7– 17	1.9(39.6)
Oxygen, dissolved (mg/L)	18	6.00– 19.0	7.04– 13.1	12.1(39.6)
Biochemical oxygen demand (mg/L)	5	1.6– 3.3	1.6– 3.0	1.6(17.6)
Hardness, total (mg/L $\text{CaCO}_3$ )	12	92– 2880	824– 2610	2610(39.6)
Calcium, dissolved (mg/L)	12	28.8– 360	103– 224	224(39.6)
Magnesium, dissolved (mg/L)	12	5.0– 496	137– 496	496(39.6)
Sodium, dissolved (mg/L)	16	19.0– 1230	55.0– 949	949(39.6)
Bicarbonate (mg/L)	16	226– 913	561– 755	579(39.6)
Carbonate (mg/L)	6	5.0– 21.0	-----	14.0(3.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	16	199– 748	460– 619	475(39.6)
Sulfate, dissolved (mg/L)	16	102– 3930	158– 3930	3930(39.6)
Chloride, dissolved (mg/L)	16	2.2– 29.1	4.2– 29.1	29.1(39.6)
Fluoride, dissolved (mg/L)	16	0.04– 1.7	0.6– 1.7	0.6(39.6)
Dissolved solids, calculated (mg/L)	12	448– 6210	2530– 6210	6210(39.6)
Sediment, total suspended (mg/L)	20	0.2–22600	1.2– 46.4	1.3(39.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	4	0.01– 0.15	0.11– 0.15	0.15(11.0)
Nitrogen, total ammonia (mg/L as N)	10	0.01– 0.21	0.06– 0.06	0.06(32.4)
Phosphorus, total (mg/L as P)	15	0.010– 0.080	0.010–0.030	0.010(39.6)
Phosphorus, total ortho (mg/L as P)	13	0.006– 0.052	0.010–0.016	0.016(32.4)
Iron, total recoverable (mg/L)	8	0.04– 0.34	0.09– 0.34	0.18(39.6)
Manganese, total recoverable (mg/L)	3	0.020– 0.060	0.020–0.060	0.020(32.4)

Ecological summary:

Prefers extremely hard, brackish waters; relatively large concentrations of inorganic nitrogen; small amounts of suspended sediment and turbidity; fine to coarse gravels (0.2– to 6–cm diameter); and small streams (0.1 to 1  $\text{ft}^3/\text{s}$ ) at higher elevations (greater than 3,000 ft) in the study area. Eurythermal between 3 and 24  $^{\circ}\text{C}$ . Fall (September to November) dominant.

Distribution summary:

Found in all hydrologic units except those representing the Powder and Little Powder Rivers. Best population development in Stroud Creek (station 39) and the upstream part of Otter Creek near the Wyoming border.



ECOTYPE: *NITZSCHIA PALEA* (KUTZ.) W. SMITH

Biotype(s):

*N. kutzingiana* Hilse var. *kutzingiana*  
\**N. palea* (Kutz.) W. Smith var. *palea*  
*N. palea* var. *tenuirostris* Grun.  
*N. paleacea* Grun. var. *paleacea*

Reference:

Hustedt, 1930b (p. 416; fig. 801)

Herbarium slide number:

1-4-10

Mean percent relative abundance:

4.5

Percent occurrence:

91.6

Abundance-occurrence index:

411.9

Preferred percent occurrence:

11.6

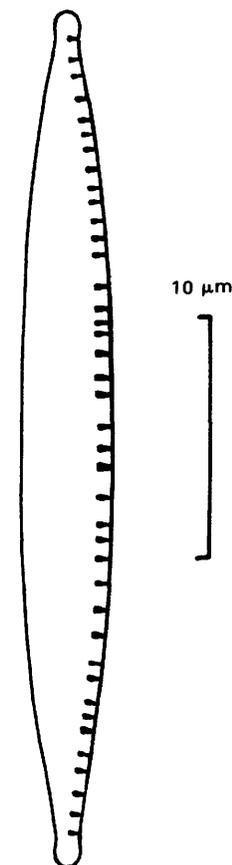
Maximum percent relative abundance:

56.6

Station number: 4

Date: May 12, 1979

Type of collection: F



Description:

Keel puncta, 12-14 in 10  $\mu\text{m}$ . Length, 35.5  $\mu\text{m}$ . Width, 3.8  $\mu\text{m}$ . The striae are extremely fine (35-40 in 10  $\mu\text{m}$ ), giving the appearance of transparency under most optical microscopes. The shape of the valve varies from linear to narrowly lanceolate. The ends are attenuated and somewhat capitate; they are never extremely protracted as in *N. acicularis* or blunt as in *N. communis*. Specimens matching the descriptions of the four biotypes often are found in the same collection, along with any number of intermediate forms. This complex, like the *Nitzschia frustulum* complex, begs rigorous taxonomic scrutiny.

Water-quality profile:

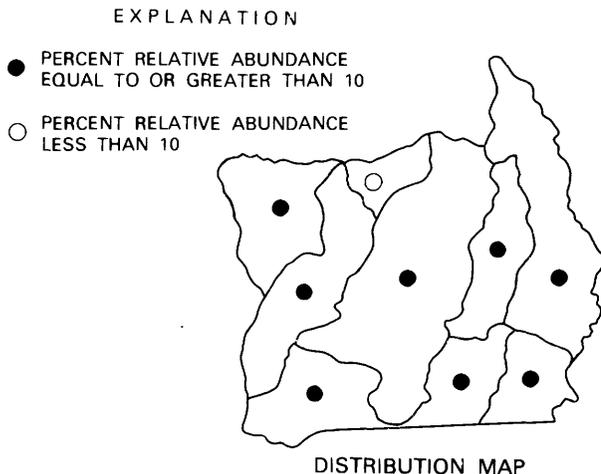
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	283	239-11000	478-6100	3280(56.6)
pH (units) -----	282	7.50- 8.80	7.60- 8.73	8.30(56.6)
Temperature ( $^{\circ}\text{C}$ ) -----	283	1.3- 30.5	3.5- 29.2	15.0(56.6)
Turbidity (NTU) -----	276	0.5-11600	1.3- 435	22(56.6)
Oxygen, dissolved (mg/L) -----	204	0.80- 19.0	6.00- 19.0	9.84(56.6)
Biochemical oxygen demand (mg/L) -----	78	0.5- 8.9	1.6- 8.9	2.7(56.6)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	169	92- 3490	236-2040	776(56.6)
Calcium, dissolved (mg/L) -----	169	16.0- 360	35.7- 254	123(56.6)
Magnesium, dissolved (mg/L) -----	169	5.0- 645	25.7- 342	114(56.6)
Sodium, dissolved (mg/L) -----	182	9.1- 1950	20.0-1230	540(56.6)
Bicarbonate (mg/L) -----	191	22- 913	198- 816	495(56.6)
Carbonate (mg/L) -----	46	0.5- 38.4	0.5- 26.0	0.5(24.1)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	191	39- 748	162- 669	406(56.6)
Sulfate, dissolved (mg/L) -----	182	17- 6900	38-5450	1450(56.6)
Chloride, dissolved (mg/L) -----	182	0.4- 174	1.2- 174	9.0(56.6)
Fluoride, dissolved (mg/L) -----	177	0.04- 1.7	0.3- 1.5	0.3(56.6)
Dissolved solids, calculated (mg/L) -----	169	196-10400	441-7680	2730(56.6)
Sediment, total suspended (mg/L) -----	256	0.2-22600	1.8- 893	45.1(56.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	133	0.01- 0.80	0.01- 0.42	0.08(18.3)
Nitrogen, total ammonia (mg/L as N) -----	164	0.01- 0.57	0.01- 0.21	0.02(56.6)
Phosphorus, total (mg/L as P) -----	196	0.010- 3.7	0.010- 0.60	0.040(56.6)
Phosphorus, total ortho (mg/L as P) -----	198	0.001- 2.5	0.002- 0.38	0.014(56.6)
Iron, total recoverable (mg/L) -----	117	0.02- 2.1	0.04- 0.79	0.22(24.1)
Manganese, total recoverable (mg/L) -----	102	0.005- 0.41	0.025- 0.37	0.10(24.1)

Ecological summary:

Very broad ecological amplitude. Prefers fresh to brackish, very hard to extremely hard waters; all substrates larger than clay and silt (greater than 0.05-mm diameter); and all stream sizes (0 to greater than 100 ft<sup>3</sup>/s) at middle and lower elevations (less than 4,000 ft). Indifferent to moderate amounts of suspended sediment, turbidity, and chloride. Spring to fall (May to October) dominant.

Distribution summary:

A dominant ecotype in all hydrologic units of the study area. This is the third most common ecotype in the southern Fort Union coal region.



ECOTYPE: *NITZSCHIA SUPRALITOREA* LANGE-BERTALOT

Biotype(s):

*N. supralitorea* Lange-Bertalot var. *supralitorea*

Reference:

Lange-Bertalot, 1979 (p. 199; figs. 25-27, 76-78)

Herbarium slide number:

1-4-12

Mean percent relative abundance:

0.1

Percent occurrence:

1.4

Abundance-occurrence index:

0.1

Preferred percent occurrence:

0.3

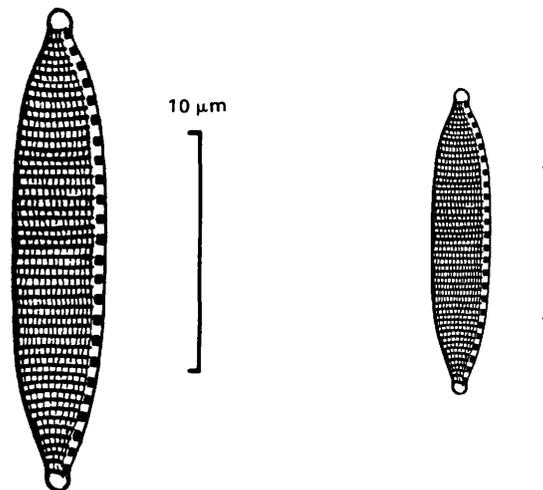
Maximum percent relative abundance:

16.5

Station number: 31

Date: August 18, 1979

Type of collection: E



Description:

Striae, 24-25 in 10  $\mu\text{m}$ . Keel puncta, 12-13 in 10  $\mu\text{m}$ . Length, 20.0  $\mu\text{m}$ . Width, 4.0  $\mu\text{m}$ . A medium *Nitzschia* with finely punctate striae, parallel sides and somewhat capitate ends. Closely resembles at least three other species that are not known to occur in the study area: striae and stria puncta are finer than in *N. bulnheimiana* var. *capitata* Reimer; sides are parallel rather than convex and ends are capitate rather than beaked as in *N. desertorum* Hust.; ends are capitate rather than short and beak-like as in *N. legleri* Hust.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	4	1250– 3290	1750– 1750	1750(16.5)
pH (units)-----	4	7.77– 8.44	7.77– 7.77	7.77(16.5)
Temperature ( $^{\circ}\text{C}$ ) -----	3	15.7– 24.0	15.7– 15.7	15.7(16.5)
Turbidity (NTU) -----	4	1.3– 435	1.3– 1.3	1.3(16.5)
Oxygen, dissolved (mg/L) -----	3	7.04– 9.52	8.48– 8.48	8.48(16.5)
Biochemical oxygen demand (mg/L)-----	0	-----	-----	-----
Hardness, total (mg/L $\text{CaCO}_3$ )-----	2	556– 709	709– 709	709(16.5)
Calcium, dissolved (mg/L)-----	2	93.5– 138	93.5– 93.5	93.5(16.5)
Magnesium, dissolved (mg/L) -----	2	51.0– 115	115– 115	115(16.5)
Sodium, dissolved (mg/L)-----	2	150– 170	150– 150	150(16.5)
Bicarbonate (mg/L) -----	2	198– 503	503– 503	503(16.5)
Carbonate (mg/L)-----	0	-----	-----	-----
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	2	162– 412	412– 412	412(16.5)
Sulfate, dissolved (mg/L)-----	2	543– 617	543– 543	543(16.5)
Chloride, dissolved (mg/L)-----	2	8.2– 88.9	8.2– 8.2	8.2(16.5)
Fluoride, dissolved (mg/L)-----	1	1.0– 1.0	1.0– 1.0	1.0(16.5)
Dissolved solids, calculated (mg/L)-----	2	1260– 1410	1410– 1410	1410(16.5)
Sediment, total suspended (mg/L)-----	3	2.2– 893	2.2– 2.2	2.2(16.5)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	3	0.02– 0.38	0.38– 0.38	0.38(16.5)
Nitrogen, total ammonia (mg/L as N)-----	3	0.01– 0.03	0.01– 0.01	0.01(16.5)
Phosphorus, total (mg/L as P) -----	3	0.010– 0.60	0.010– 0.010	0.010(16.5)
Phosphorus, total ortho (mg/L as P) -----	3	0.006– 0.38	0.006– 0.006	0.006(16.5)
Iron, total recoverable (mg/L) -----	1	0.12– 0.12	0.12– 0.12	0.12(16.5)
Manganese, total recoverable (mg/L) -----	1	0.035– 0.035	0.035– 0.035	0.035(16.5)

Ecological summary:

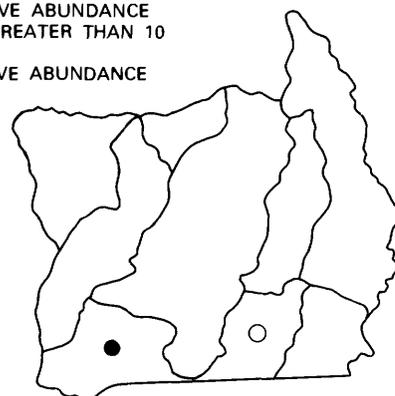
Prefers brackish waters; relatively large concentrations of inorganic nitrogen; small streams at middle elevations (3,000 to 3,500 ft); and small amounts of suspended sediment and turbidity. Summer (August) dominant.

Distribution summary:

Rare. Prairie Dog Creek near Birney (station 31) and the Powder River near Broadus (station 46) produced the only populations in the study area.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *NITZSCHIA VALDESTRIATA* ALEEM & HUST.

Biotype(s):

*N. valdestriata* Aleem & Hust. var. *valdestriata*

Reference:

Foged, 1978 (p. 112; pl. 46, fig. 24)

Herbarium slide number:

1-4-11

Mean percent relative abundance:

0.2

Percent occurrence:

19.2

Abundance-occurrence index:

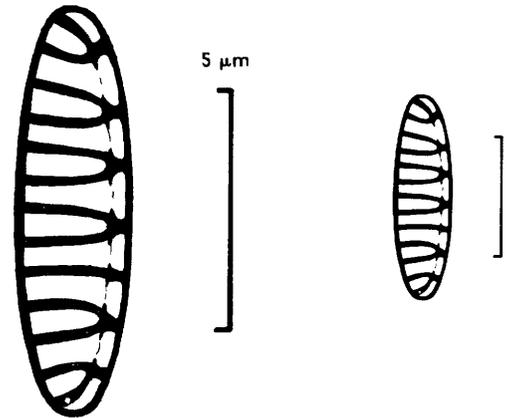
3.2

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

13.3



Station number: 4

Date: July 31, 1978

Type of collection: F

Description:

Striae, 7-8 in 10  $\mu\text{m}$ . Keel puncta, 4-5 in 10  $\mu\text{m}$ . Length, 8.5  $\mu\text{m}$ . Width, 2.5  $\mu\text{m}$ . This is a very small *Nitzschia* with blunt ends and very coarse striae and keel puncta.

## Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	57	542- 6100	910- 910	910(13.3)
pH (units) -----	57	7.65- 8.60	7.82- 7.82	7.82(13.3)
Temperature ( $^{\circ}\text{C}$ ) -----	57	2.0- 30.5	22.0- 22.0	22.0(13.3)
Turbidity (NTU) -----	56	0.8-11600	11600-11600	11600(13.3)
Oxygen, dissolved (mg/L) -----	37	0.80- 13.4	6.90- 6.90	6.90(13.3)
Biochemical oxygen demand (mg/L) -----	16	0.5- 8.3	-----	1.5(1.1)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	34	92- 2110	92- 92	92(13.3)
Calcium, dissolved (mg/L) -----	34	16.0- 257	28.8- 28.8	28.8(13.3)
Magnesium, dissolved (mg/L)-----	34	5.0- 357	5.0- 5.0	5.0(13.3)
Sodium, dissolved (mg/L) -----	34	31.1- 1040	205- 205	205(13.3)
Bicarbonate (mg/L)-----	37	171- 776	370- 370	370(13.3)
Carbonate (mg/L) -----	5	0.5- 12.0	-----	12.0(0.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	37	146- 636	303- 303	303(13.3)
Sulfate, dissolved (mg/L) -----	34	116- 3350	380- 380	380(13.3)
Chloride, dissolved (mg/L) -----	34	2.2- 51.6	2.2- 2.2	2.2(13.3)
Fluoride, dissolved (mg/L) -----	33	0.04- 1.1	0.6- 0.6	0.6(13.3)
Dissolved solids, calculated (mg/L) -----	34	416- 5560	992- 992	992(13.3)
Sediment, total suspended (mg/L) -----	51	0.7-22600	22600-22600	22600(13.3)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	18	0.01- 0.64	-----	0.01(6.3)
Nitrogen, total ammonia (mg/L as N) -----	33	0.01- 0.11	-----	0.03(2.7)
Phosphorus, total (mg/L as P)-----	37	0.010- 0.25	-----	0.010(6.3)
Phosphorus, total ortho (mg/L as P)-----	37	0.001- 0.15	-----	0.005(2.7)
Iron, total recoverable (mg/L)-----	14	0.08- 0.51	-----	0.34(2.7)
Manganese, total recoverable (mg/L)-----	14	0.015- 0.26	-----	0.054(2.7)

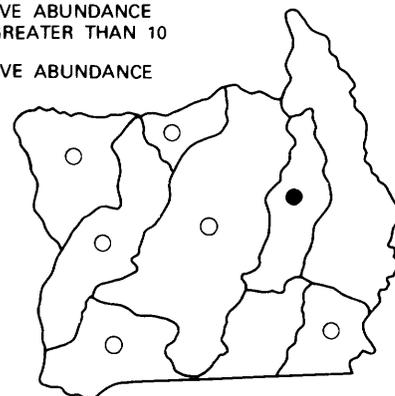
### Ecological summary:

Prefers fresh, moderately hard water of large sodium concentration; fine to medium gravels (0.2- to 3-cm diameter); and larger streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 2,500 ft). Tolerates very large amounts of suspended sediment and turbidity. Summer (July) dominant.

### Distribution summary:

Widespread but rarely found in abundance. Best population development in Mizpah Creek.

- EXPLANATION
- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
  - PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *PLEUROSIGMA DELICATULUM* W. SM.

Biotype(s):

*P. delicatulum* W. Sm. var. *delicatulum*

Reference:

Patrick and Reimer, 1966 (p. 336; pl. 28, figs. 4a-b)

Herbarium slide number:

1-4-13

Mean percent relative abundance:

0.7

Percent occurrence:

51.1

Abundance-occurrence index:

34.3

Preferred percent occurrence:

0.8

Maximum percent relative abundance:

13.4

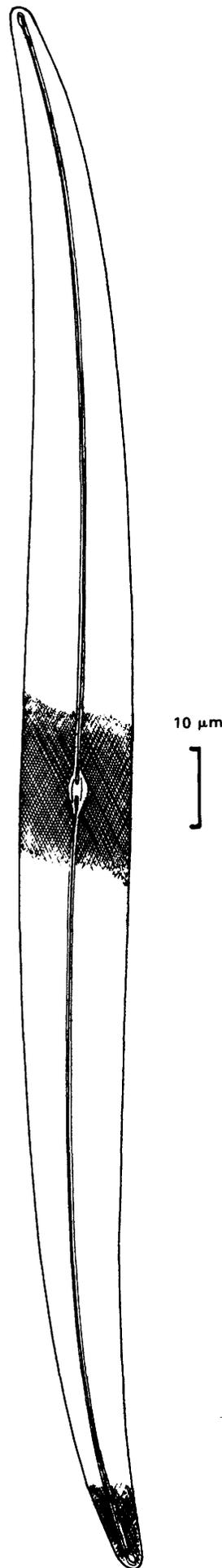
Station number: 14; 30

Date: October 9, 1978; August 29, 1978

Type of collection: F; E

Description:

Striae, 19-22 in 10  $\mu\text{m}$ . Length, 200.0  $\mu\text{m}$ . Width, 14.3  $\mu\text{m}$ . A very large diatom with a sigmoid outline. This is the only species of *Pleurosigma* found to date in the study area. Distinguished from species of *Gyrosigma* in that the striae run diagonally across the valve rather than at right angles to the transverse and apical axes.



Water-quality profile:

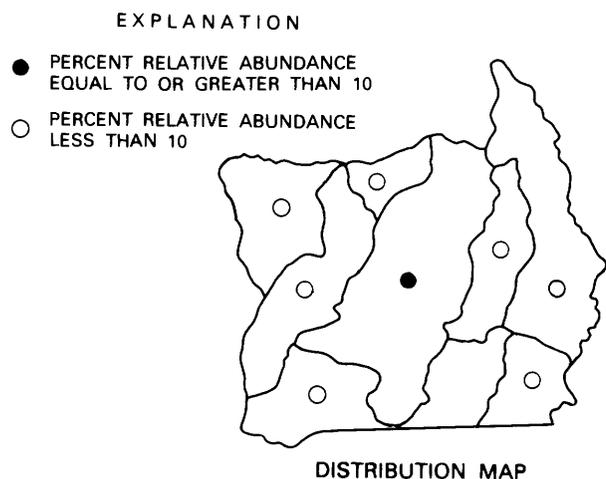
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	160	540-11000	540- 3160	3160(13.4)
pH (units)	160	7.41- 8.73	8.20- 8.59	8.20(13.4)
Temperature ( $^{\circ}\text{C}$ )	160	2.0- 30.5	7.2- 21.9	17.8(13.4)
Turbidity (NTU)	155	0.6-11600	4.4- 12	4.4(13.4)
Oxygen, dissolved (mg/L)	122	1.85- 19.0	10.9- 10.9	10.9(13.4)
Biochemical oxygen demand (mg/L)	46	0.5- 8.3		2.8(9.0)
Hardness, total (mg/L $\text{CaCO}_3$ )	94	92- 3490	273- 1180	1180(13.4)
Calcium, dissolved (mg/L)	94	16.0- 360	57.6- 143	143(13.4)
Magnesium, dissolved (mg/L)	94	5.0- 645	31.4- 200	200(13.4)
Sodium, dissolved (mg/L)	99	19.0- 1950	19.0- 405	378(13.4)
Bicarbonate (mg/L)	103	148- 809	226- 798	498(13.4)
Carbonate (mg/L)	23	0.5- 36.0	8.2- 8.2	8.2(11.3)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	103	133- 664	199- 654	408(13.4)
Sulfate, dissolved (mg/L)	99	102- 6900	102- 1440	1440(13.4)
Chloride, dissolved (mg/L)	99	1.2- 126	3.1- 12.5	12.5(13.4)
Fluoride, dissolved (mg/L)	97	0.04- 1.7	0.3- 0.6	0.6(13.4)
Dissolved solids, calculated (mg/L)	94	448-10400	448- 2690	2670(13.4)
Sediment, total suspended (mg/L)	145	0.2-22600	10.1- 13.3	10.1(13.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	69	0.01- 0.71	0.01- 0.22	0.22(13.4)
Nitrogen, total ammonia (mg/L as N)	91	0.01- 0.57	0.01- 0.04	0.04(13.4)
Phosphorus, total (mg/L as P)	103	0.010- 0.62	0.020-0.057	0.020(13.4)
Phosphorus, total ortho (mg/L as P)	104	0.001- 0.52	0.005-0.033	0.005(13.4)
Iron, total recoverable (mg/L)	61	0.02- 2.1	0.34- 0.39	0.34(13.4)
Manganese, total recoverable (mg/L)	55	0.005- 0.41	0.12- 0.14	0.14(13.4)

Ecological summary:

Prefers fresh to brackish waters with small amounts of suspended sediment and turbidity; coarse sand to fine gravel substrates (0.03- to 1-cm diameter); and small to medium streams (0.1 to 10  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft) in the study area. Late summer and fall (August to October) dominant.

Distribution summary:

Widespread and commonly found in the study area, but seldom in abundance. Best population development in certain tributaries of the Tongue River.



ECOTYPE: *RHOICOSPHENIA CURVATA* (KUTZ.) GRUN. EX RABH.

Biotype(s):

*R. curvata* (Kutz.) Grun. ex Rabh. var. *curvata*

Reference:

Patrick and Reimer, 1966 (p. 282; pl. 20, figs. 1-5)

Herbarium slide number:

1-4-14

Mean percent relative abundance:

2.2

Percent occurrence:

74.3

Abundance-occurrence index:

162.1

Preferred percent occurrence:

4.6

Maximum percent relative abundance:

67.6

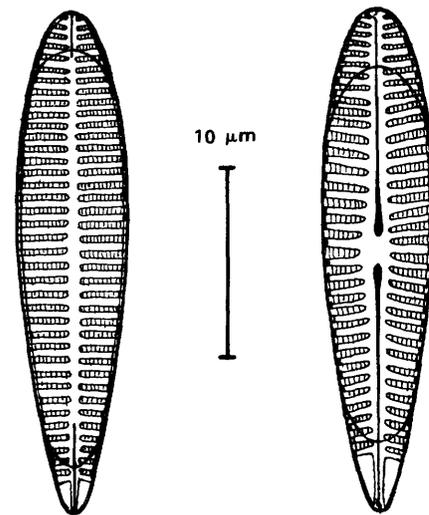
Station number: 8

Date: June 19, 1980

Type of collection: E

Description:

Striae, 12-18 in 10  $\mu\text{m}$  on raphe valve and 14-18 in 10  $\mu\text{m}$  on rudimentary raphe valve. Length, 26.0  $\mu\text{m}$ . Width, 6.0  $\mu\text{m}$ . Like species of *Achnanthes* and *Cocconeis*, *Rhoicosphenia curvata* has a fully developed raphe on one valve only and is arched in girdle view. Unlike members of these other two genera, *R. curvata* is heteropolar and has a well-developed pseudoseptum at each end of both valves. It attaches to the substrate by a stalk. This is the only species of this genus found in the study area.



Rudimentary raphe valve

Raphe valve

## Water-quality profile:

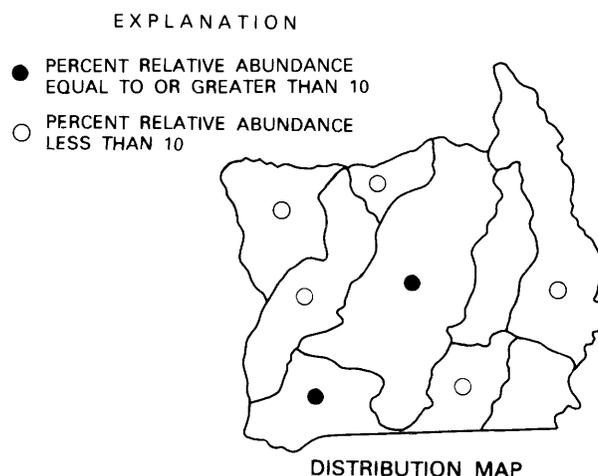
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	219	239–11000	510– 4200	2810(27.3)
pH (units)	219	7.62– 8.72	8.00– 8.59	8.29(27.3)
Temperature ( $^{\circ}\text{C}$ )	218	1.7– 30.2	6.2– 25.5	19.2(27.3)
Turbidity (NTU)	214	0.5– 435	1.4– 67	25(27.3)
Oxygen, dissolved (mg/L)	159	4.52– 19.0	6.80– 12.7	6.80(27.3)
Biochemical oxygen demand (mg/L)	63	0.5– 8.9	2.5– 3.2	3.2(27.3)
Hardness, total (mg/L $\text{CaCO}_3$ )	133	124– 3490	273– 1400	1050(17.5)
Calcium, dissolved (mg/L)	133	27.4– 330	57.2– 192	88.0(17.5)
Magnesium, dissolved (mg/L)	133	13.5– 645	31.4– 224	202(17.5)
Sodium, dissolved (mg/L)	138	9.1– 1950	19.0– 622	404(17.5)
Bicarbonate (mg/L)	145	15– 816	22– 576	566(17.5)
Carbonate (mg/L)	32	0.5– 36.0	8.2– 36.0	36.0(17.5)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	145	13– 669	180– 524	524(17.5)
Sulfate, dissolved (mg/L)	138	17– 6900	102– 2200	1270(17.5)
Chloride, dissolved (mg/L)	138	0.4– 126	2.8– 15.0	9.9(17.5)
Fluoride, dissolved (mg/L)	134	0.1– 1.7	0.3– 1.0	0.7(17.5)
Dissolved solids, calculated (mg/L)	133	184–10400	290– 3830	2580(17.5)
Sediment, total suspended (mg/L)	201	0.2– 893	2.9– 127	26.8(17.5)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	108	0.01– 0.71	0.01– 0.06	0.02(15.0)
Nitrogen, total ammonia (mg/L as N)	123	0.01– 0.57	0.01– 0.03	0.03(15.0)
Phosphorus, total (mg/L as P)	153	0.010– 0.62	0.020– 0.12	0.050(15.0)
Phosphorus, total ortho (mg/L as P)	152	0.001– 0.52	0.002– 0.069	0.052(15.0)
Iron, total recoverable (mg/L)	88	0.02– 2.1	0.21– 0.21	0.21(10.7)
Manganese, total recoverable (mg/L)	82	0.005– 0.41	0.064– 0.064	0.064(10.7)

## Ecological summary:

Prefers fresh to brackish waters; fine to coarse gravels (0.2– to 6–cm diameter); and middle elevations (2,500 to 4,000 ft). Tolerates some suspended sediment and turbidity. Apparently indifferent to season and stream size. Eurythermal between 6 and 26  $^{\circ}\text{C}$ . Requires stable attachment sites.

## Distribution summary:

Widespread. Best population development in the Tongue River drainage.



ECOTYPE: *RHOPALODIA GIBBA* (EHR.) O. MULL.

Biotype(s):

\**R. gibba* (Ehr.) O. Mull. var. *gibba*  
*R. gibba* var. *ventricosa* (Kutz.) H. & M. Perag.

Reference:

Patrick and Reimer, 1975 (p. 189; pl. 28, fig. 1)

Herbarium slide number:

1-4-5

Mean percent relative abundance:

0.3

Percent occurrence:

35.9

Abundance-occurrence index:

10.4

Preferred percent occurrence:

0.3

Maximum percent relative abundance:

11.0

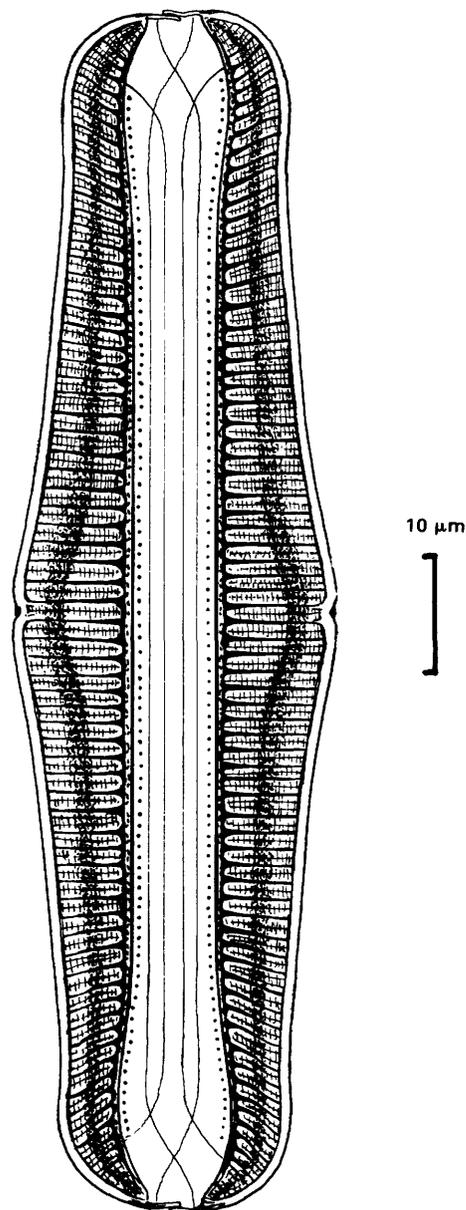
Station number: 14

Date: July 18, 1979

Type of collection: E

Description:

Costae, 7-8 in 10  $\mu\text{m}$ . Rows of alveoli, 13-16 in 10  $\mu\text{m}$ . Length, 100.0  $\mu\text{m}$ . Width (frustule in valve-girdle view), 27.5  $\mu\text{m}$ . A large diatom of complex structure, generally found in valve-girdle view. Distinguished from the other two species of *Rhopalodia* from the study area—*R. gibberula* (Ehr.) O. Mull. and *R. musculus* (Kutz.) O. Mull.—by its large size, characteristic shape, and median notch on the margin of each valve. The two biotypes of *R. gibba* frequently compose a size and morphological continuum in our collections, and the principal author questions whether they warrant varietal distinction.



Water-quality profile:

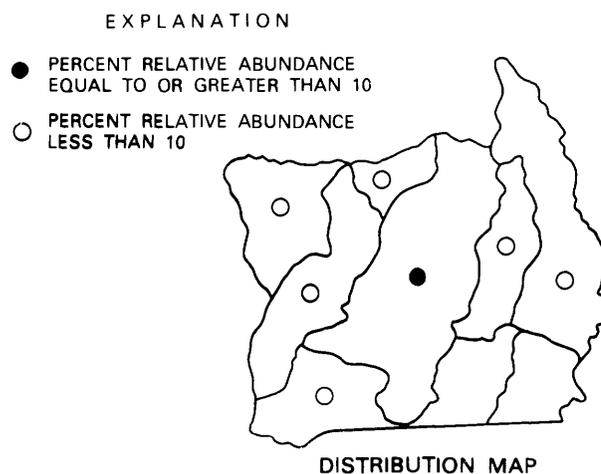
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu$ mho/cm)	115	462-7030		5200(8.3)
pH (units)	115	7.50- 8.80		8.02(8.3)
Temperature ( $^{\circ}$ C)	116	1.3- 30.5		27.3(8.3)
Turbidity (NTU)	111	0.7- 150		15(8.3)
Oxygen, dissolved (mg/L)	74	4.52- 19.0		9.40(8.3)
Biochemical oxygen demand (mg/L)	28	0.5- 8.3		1.8(8.3)
Hardness, total (mg/L CaCO <sub>3</sub> )	75	123-3320		1610(8.3)
Calcium, dissolved (mg/L)	75	16.0- 360		222(8.3)
Magnesium, dissolved (mg/L)	75	18.3- 605		256(8.3)
Sodium, dissolved (mg/L)	80	12.2-1470		820(8.3)
Bicarbonate (mg/L)	86	148- 913		588(8.3)
Carbonate (mg/L)	24	0.5- 38.4		21.0(2.0)
Alkalinity, total (mg/L CaCO <sub>3</sub> )	86	133- 748		482(8.3)
Sulfate, dissolved (mg/L)	80	17-4040		2850(8.3)
Chloride, dissolved (mg/L)	80	0.4- 54.6		23.8(8.3)
Fluoride, dissolved (mg/L)	78	0.04- 1.7		0.4(8.3)
Dissolved solids, calculated (mg/L)	75	389-6290		4760(8.3)
Sediment, total suspended (mg/L)	108	0.2- 323		24.6(8.3)
Nitrogen, total NO <sub>2</sub> +NO <sub>3</sub> (mg/L as N)	43	0.01- 0.64		0.06(4.5)
Nitrogen, total ammonia (mg/L as N)	63	0.01- 0.57		0.17(5.8)
Phosphorus, total (mg/L as P)	83	0.010- 0.25		0.030(8.3)
Phosphorus, total ortho (mg/L as P)	82	0.001- 0.22		0.006(8.3)
Iron, total recoverable (mg/L)	53	0.02- 0.75		0.32(8.3)
Manganese, total recoverable (mg/L)	45	0.010- 0.41		0.12(8.3)

Ecological summary:

Prefers warm, brackish, sodium sulfate waters; fine to medium gravels (0.2- to 3-cm diameter); and small streams (0 to 1 ft<sup>3</sup>/s) at middle elevations (2,500 to 3,000 ft). Summer (June to August) dominant.

Distribution summary:

Widespread but rarely abundant. Best population development in Beaver Creek near Ashland (station 14).



ECOTYPE: *STEPHANODISCUS ASTRAEA* VAR. *MINUTULA* (KUTZ.) GRUN.

Biotype(s):

*S. astraea* var. *minutula* (Kutz.) Grun.

Reference:

Hustedt, 1930a (p. 369; figs. 193d-e)

Herbarium slide number:

1-4-16

Mean percent relative abundance:

0.4

Percent occurrence:

18.6

Abundance-occurrence index:

8.0

Preferred percent occurrence:

0.8

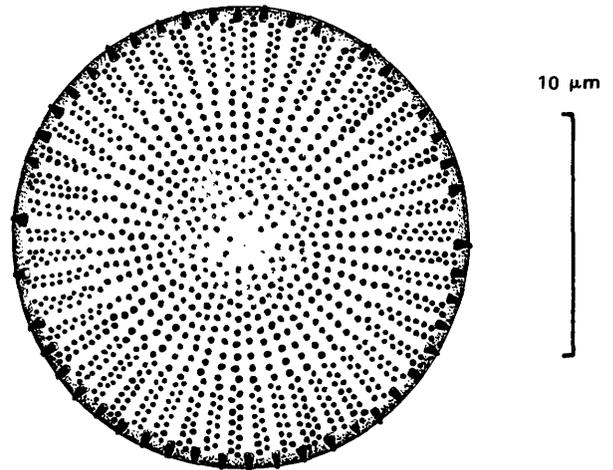
Maximum percent relative abundance:

35.6

Station number: 51

Date: May 29, 1976

Type of collection: A



Description:

Striae, 18-20 in 10  $\mu\text{m}$ . Diameter, 19.0  $\mu\text{m}$ . A small to medium *Stephanodiscus*, ranging in size from less than 10 to nearly 30  $\mu\text{m}$  in diameter. Several features distinguish this diatom from *S. niagarae*: The spines are smaller, more regularly spaced, and inserted closer to the valve margin; no striae are visible on the valve mantle; no central strutted processes are present; the striae and the puncta composing the striae are finer; and the overall size is generally smaller. The principal author considers *S. astraea* var. *minutula* to be synonymous with *S. minutus* Cleve and Moller. Only in the plankton in water from the Tongue River Reservoir do specimens of this taxon get larger than 15  $\mu\text{m}$  in diameter; elsewhere in the study area, in stream collections, they are generally in the range of 8 to 12  $\mu\text{m}$  in diameter.

Water-quality profile:

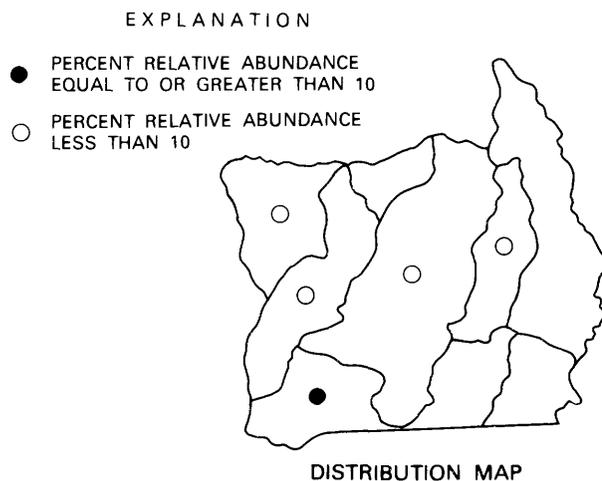
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	44	239–3310	822– 1250	1250(10.1)
pH (units)	43	7.80– 8.50	8.44– 8.44	8.44(10.1)
Temperature ( $^{\circ}\text{C}$ )	42	2.0– 26.0	-----	9.3(9.6)
Turbidity (NTU)	38	1.2– 150	7.0– 67	67(10.1)
Oxygen, dissolved (mg/L)	31	7.04– 13.8	9.52– 9.52	9.52(10.1)
Biochemical oxygen demand (mg/L)	13	0.5– 7.8	-----	0.5(9.6)
Hardness, total (mg/L $\text{CaCO}_3$ )	22	124–1120	-----	758(9.6)
Calcium, dissolved (mg/L)	22	27.4– 123	-----	114(9.6)
Magnesium, dissolved (mg/L)	22	13.5– 208	-----	115(9.6)
Sodium, dissolved (mg/L)	22	9.1– 540	-----	385(9.6)
Bicarbonate (mg/L)	28	15– 661	-----	616(9.6)
Carbonate (mg/L)	6	3.0– 7.0	-----	5.0(8.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	28	13– 542	-----	505(9.6)
Sulfate, dissolved (mg/L)	22	34–1450	-----	1040(9.6)
Chloride, dissolved (mg/L)	22	1.3– 16.8	-----	12.2(9.6)
Fluoride, dissolved (mg/L)	21	0.1– 1.1	-----	1.1(9.6)
Dissolved solids, calculated (mg/L)	22	184–2880	-----	2300(9.6)
Sediment, total suspended (mg/L)	42	0.9– 323	13.1– 127	127(10.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	17	0.01– 0.29	0.02– 0.02	0.02(10.1)
Nitrogen, total ammonia (mg/L as N)	17	0.01– 0.06	0.03– 0.03	0.03(10.1)
Phosphorus, total (mg/L as P)	32	0.010– 0.25	0.050–0.050	0.050(10.1)
Phosphorus, total ortho (mg/L as P)	32	0.001– 0.15	0.052–0.052	0.052(10.1)
Iron, total recoverable (mg/L)	13	0.04– 0.83	-----	0.28(9.6)
Manganese, total recoverable (mg/L)	11	0.019– 0.12	-----	0.050(9.6)

Ecological summary:

Prefers cool, fresh to somewhat brackish waters; fine to medium gravels (0.2– to 3–cm diameter); and larger streams (greater than 1  $\text{ft}^3/\text{s}$ ) at all but the highest elevations (less than 4,000 ft). Tolerates some suspended sediment and turbidity. Spring (May) dominant. Euplanktonic and tychoplanktonic.

Distribution summary:

Found in all hydrologic units except those representing the Powder River and the Little Powder River. Best population development (and the largest specimens) in the Tongue River Reservoir.



ECOTYPE: *STEPHANODISCUS NIAGARAE* EHR.

Biotype(s):

*S. niagarae* Ehr. var. *niagarae*

Reference:

Collins and Kalinsky, 1977 (p. 21; pl. VIII, fig. 9)

Herbarium slide number:

1-4-15

Mean percent relative abundance:

0.2

Percent occurrence:

10.5

Abundance-occurrence index:

1.7

Preferred percent occurrence:

0.3

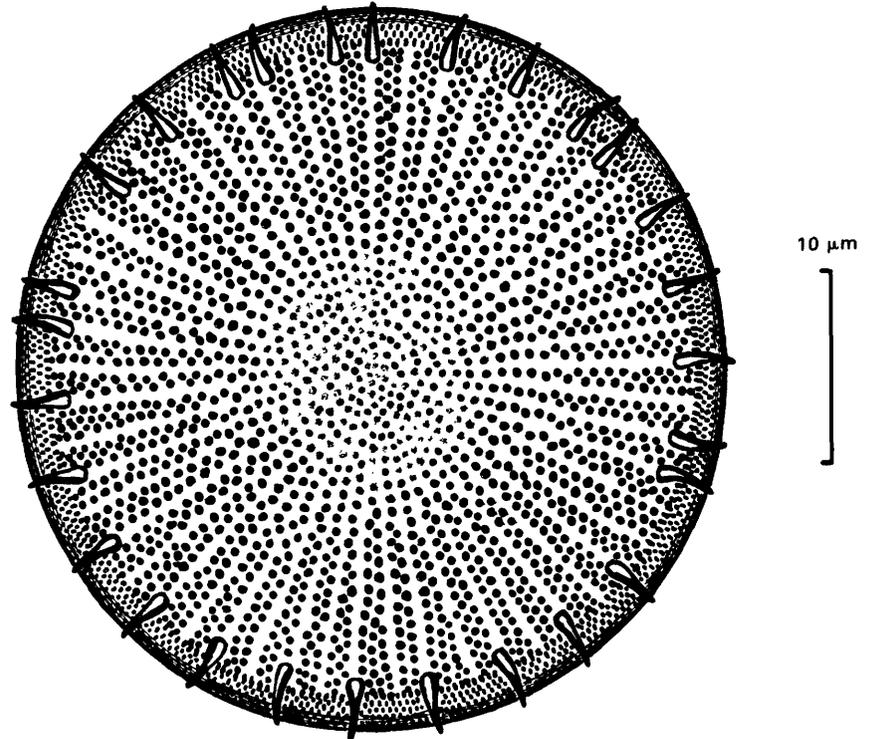
Maximum percent relative abundance:

31.3

Station number: 51

Date: October 16, 1976

Type of collection: A



Description:

Striae, 14 in 10  $\mu\text{m}$ . Diameter, 38.0  $\mu\text{m}$ . This is the largest of the common centric diatoms in the study area. (*Biddulphia laevis* Ehr. is considerably larger but rare.) Distinguished from *S. astraea* (Ehr.) Grun. in that the spines are larger and inserted submarginally, finely punctate striae are visible on the valve mantle, and a variable number of central strutted processes (not illustrated) are present.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	20	542–3290		876(6.2)
pH (units)	19	7.80– 8.50		8.27(6.2)
Temperature ( $^{\circ}\text{C}$ )	19	2.0– 26.0		10.1(6.2)
Turbidity (NTU)	14	1.4– 94		7.0(4.8)
Oxygen, dissolved (mg/L)	14	7.04– 13.8		10.2(6.2)
Biochemical oxygen demand (mg/L)	9	0.5– 3.3		3.3(6.2)
Hardness, total (mg/L $\text{CaCO}_3$ )	13	222– 758		392(6.2)
Calcium, dissolved (mg/L)	13	42.1– 114		77.0(6.2)
Magnesium, dissolved (mg/L)	13	28.3– 115		48.5(6.2)
Sodium, dissolved (mg/L)	13	26.9– 385		47.0(6.2)
Bicarbonate (mg/L)	14	22– 616		289(6.2)
Carbonate (mg/L)	5	3.0– 6.0		6.0(0.9)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	14	146– 505		237(6.2)
Sulfate, dissolved (mg/L)	13	116–1040		234(6.2)
Chloride, dissolved (mg/L)	13	2.7– 12.2		3.6(6.2)
Fluoride, dissolved (mg/L)	12	0.3– 1.1		0.3(6.2)
Dissolved solids, calculated (mg/L)	13	290–2300		705(6.2)
Sediment, total suspended (mg/L)	19	0.9– 310		7.5(6.2)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	8	0.01– 0.29		0.02(2.3)
Nitrogen, total ammonia (mg/L as N)	6	0.01– 0.06		0.03(6.2)
Phosphorus, total (mg/L as P)	15	0.010– 0.25		0.015(6.2)
Phosphorus, total ortho (mg/L as P)	14	0.002– 0.15		0.003(6.2)
Iron, total recoverable (mg/L)	9	0.04– 0.60		0.12(6.2)
Manganese, total recoverable (mg/L)	8	0.015– 0.12		0.12(6.2)

Ecological summary:

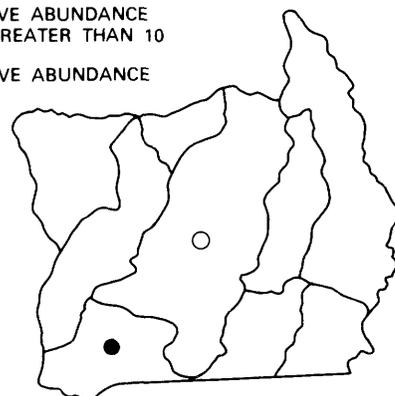
Prefers cool, fresh waters with small amounts of suspended sediment and turbidity; and large streams (greater than 100  $\text{ft}^3/\text{s}$ ) at lower elevations (2,500 to 3,000 ft). Euplanktonic. Fall (October) dominant.

Distribution summary:

Found in the Tongue River Reservoir and incidental to the Tongue River downstream from the reservoir.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *STEPHANODISCUS SUBTILIS* VAN GOOR

Biotype(s):

*S. subtilis* Van Goor var. *subtilis*

Reference:

Bradbury, 1975 (p. 58; pl. 1, figs. 5-6; pl. 4, fig. 3)

Herbarium slide number:

1-4-17

Mean percent relative abundance:

0.6

Percent occurrence:

16.5

Abundance-occurrence index:

9.8

Preferred percent occurrence:

1.6

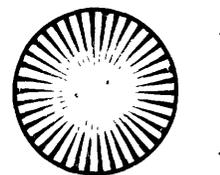
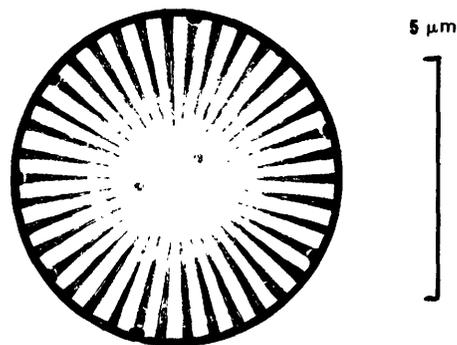
Maximum percent relative abundance:

80.0

Station number: 51

Date: May 14, 1976

Type of collection: A



Description:

Striae, 20 in 10 μm. Diameter, 7.0 μm. A small, very delicately ornamented *Stephanodiscus* with very subtle spines at the valve margin between the striae. Striae composed of one and two rows of very fine puncta, which are not visible under most optical microscopes. Distinguished from other common species of this genus by the very fine features and from *Cyclotella pseudostelligera* by the absence of a central rosette.

## Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	49	239- 4890	822- 1460	822(80.0)
pH (units) -----	48	7.70- 8.72	8.28- 8.50	8.50(19.9)
Temperature ( $^{\circ}\text{C}$ ) -----	46	3.3- 26.0	3.3- 21.9	3.3(19.9)
Turbidity (NTU) -----	49	0.8- 435	7.0- 150	7.0(80.0)
Oxygen, dissolved (mg/L) -----	32	7.04- 13.1	8.21- 12.8	12.8(19.9)
Biochemical oxygen demand (mg/L) -----	9	1.4- 3.3	-----	3.3(2.5)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	28	124- 900	561- 617	617(14.6)
Calcium, dissolved (mg/L) -----	28	27.4- 143	63.2- 68.9	63.2(14.6)
Magnesium, dissolved (mg/L) -----	28	13.5- 147	94.0- 112	112(14.6)
Sodium, dissolved (mg/L) -----	30	9.1- 384	71.0- 133	133(14.6)
Bicarbonate (mg/L) -----	32	45- 561	429- 460	460(14.6)
Carbonate (mg/L) -----	15	1.0-10.00	7.0- 7.0	7.0(14.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	32	39- 460	364- 389	389(14.6)
Sulfate, dissolved (mg/L) -----	30	34- 1200	314- 481	481(14.6)
Chloride, dissolved (mg/L) -----	30	1.3- 174	5.5- 5.6	5.5(14.6)
Fluoride, dissolved (mg/L) -----	26	0.1- 1.5	0.6- 0.6	0.6(14.6)
Dissolved solids, calculated (mg/L) -----	28	196- 2390	990- 1260	1260(14.6)
Sediment, total suspended (mg/L) -----	45	0.9- 893	13.1- 323	13.1(80.0)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	19	0.01- 0.32	0.02- 0.02	0.02(10.1)
Nitrogen, total ammonia (mg/L as N) -----	25	0.01- 0.11	0.01- 0.03	0.01(14.6)
Phosphorus, total (mg/L as P) -----	36	0.010- 0.60	0.040-0.078	0.040(19.9)
Phosphorus, total ortho (mg/L as P) -----	36	0.002- 0.38	0.008-0.052	0.015(19.9)
Iron, total recoverable (mg/L) -----	17	0.05- 1.4	-----	0.08(7.9)
Manganese, total recoverable (mg/L) -----	14	0.019- 0.15	-----	0.019(7.9)

## Ecological summary:

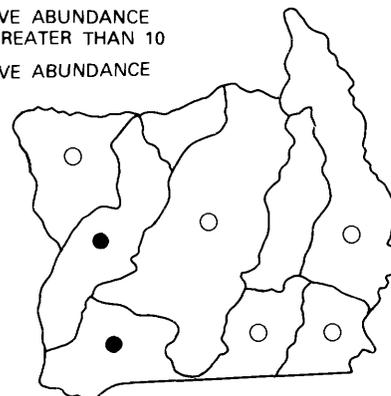
Prefers fresh to slightly brackish waters; fine gravels or larger (greater than 0.2-cm diameter); and medium streams (10 to 100  $\text{ft}^3/\text{s}$ ) at lower elevations (less than 3,000 ft). Eurythermal between 3 and 22  $^{\circ}\text{C}$ . Tolerates large amounts of suspended sediment and turbidity. Spring (May) dominant. Euplanktonic and tychoplanktonic.

## Distribution summary:

Widespread. Best population development in the Tongue River Reservoir and the downstream part of Rosebud Creek.

## EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *SURIRELLA OVATA* KUTZ.

Biotype(s):

\**S. ovata* Kutz. var. *ovata*  
*S. ovata* var. *pinnata* (W. Sm.) Hust.

Reference:

Hustedt, 1930b (p. 442; figs. 863-864)

Herbarium slide number:

1-4-18

Mean percent relative abundance:

1.3

Percent occurrence:

67.6

Abundance-occurrence index:

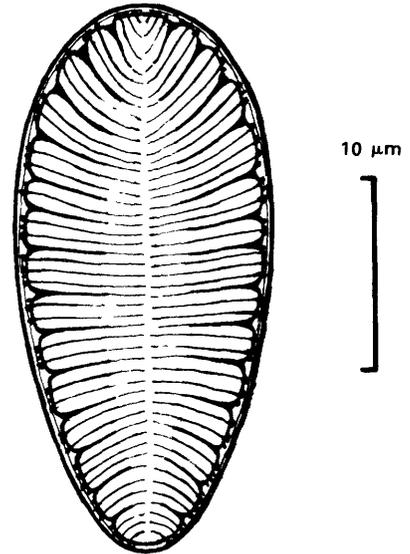
91.2

Preferred percent occurrence:

2.4

Maximum percent relative abundance:

28.1



Station number: 34

Date: May 28, 1978

Type of collection: E

Description:

Striae, 16-18 in 10  $\mu\text{m}$ . Ribs, 4-5 in 10  $\mu\text{m}$ .  
Length, 28.4  $\mu\text{m}$ . Width, 13.8  $\mu\text{m}$ . A small egg-shaped diatom; this is the smallest and most common species of *Surirella* in the study area.

Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	208	239–8700	1280– 2100	2080(28.1)
pH (units)	207	7.50– 8.80	8.10– 8.42	8.33(28.1)
Temperature ( $^{\circ}\text{C}$ )	209	1.0– 30.2	4.1– 21.2	20.0(28.1)
Turbidity (NTU)	206	0.5–4200	0.9– 11	6.6(28.1)
Oxygen, dissolved (mg/L)	156	5.40– 15.0	9.55– 12.3	10.4(28.1)
Biochemical oxygen demand (mg/L)	62	0.5– 8.9	2.4– 2.4	2.4(14.1)
Hardness, total (mg/L $\text{CaCO}_3$ )	125	124–2880	496– 967	496(16.1)
Calcium, dissolved (mg/L)	125	27.4– 360	82.8– 121	82.8(16.1)
Magnesium, dissolved (mg/L)	125	13.5– 482	70.0– 161	70.0(16.1)
Sodium, dissolved (mg/L)	134	9.1–1770	100– 138	124(16.1)
Bicarbonate (mg/L)	138	111– 913	393– 636	478(16.1)
Carbonate (mg/L)	30	0.5– 38.4	1.0– 1.0	1.0(16.1)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	138	91– 748	322– 521	394(16.1)
Sulfate, dissolved (mg/L)	134	34–5290	285– 770	285(16.1)
Chloride, dissolved (mg/L)	134	0.4– 174	3.5– 51.6	4.9(16.1)
Fluoride, dissolved (mg/L)	131	0.1– 1.5	0.5– 1.0	1.0(16.1)
Dissolved solids, calculated (mg/L)	125	196–5560	1050– 1780	1050(16.1)
Sediment, total suspended (mg/L)	189	0.2–3220	4.2– 23.2	9.6(18.7)
Nitrogen, total $\text{NO}_2+\text{NO}_3$ (mg/L as N)	107	0.01– 0.71	0.03– 0.13	0.13(14.1)
Nitrogen, total ammonia (mg/L as N)	122	0.01– 0.57	0.01– 0.04	0.01(16.1)
Phosphorus, total (mg/L as P)	143	0.010– 2.6	0.010–0.020	0.020(14.1)
Phosphorus, total ortho (mg/L as P)	147	0.001– 1.8	0.005–0.010	0.005(16.1)
Iron, total recoverable (mg/L)	85	0.02– 2.1	0.08– 0.10	0.10(14.1)
Manganese, total recoverable (mg/L)	76	0.005– 0.39	0.030–0.030	0.030(11.7)

Ecological summary:

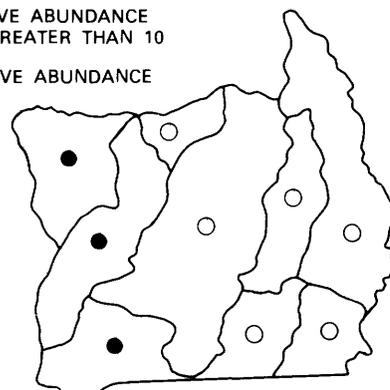
Prefers slightly brackish waters; sand substrates (0.05– to 2–mm diameter); and small streams (0.1 to 10  $\text{ft}^3/\text{s}$ ) at middle elevations (2,500 to 4,000 ft). Eurythermal between 4 and 22  $^{\circ}\text{C}$ . Tolerates small amounts of suspended sediment and turbidity. Spring (March to June) dominant.

Distribution summary:

Found throughout the study area; best population development in the western part.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *SYNEDRA FAMELICA* KUTZ.

Biotype(s):

*S. famelica* Kutz. var. *famelica*

Reference:

Patrick and Reimer, 1966 (p. 139; pl. 5, fig. 9)

Herbarium slide number:

1-4-19

Mean percent relative abundance:

0.8

Percent occurrence:

35.4

Abundance-occurrence index:

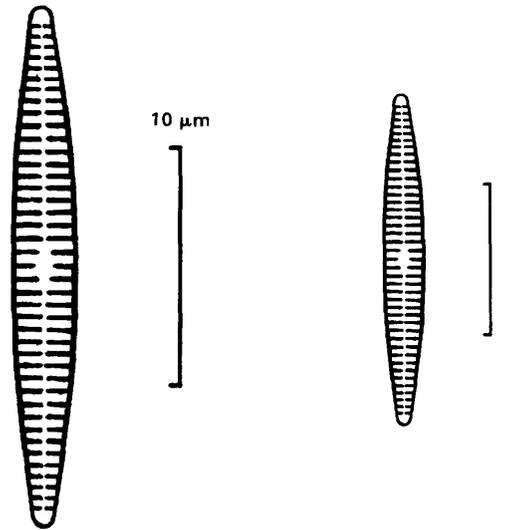
27.1

Preferred percent occurrence:

2.2

Maximum percent relative abundance:

30.9



Station number: 18

Date: May 20, 1979

Type of collection: E

Description:

Striae, 20-21 in 10  $\mu\text{m}$ . Length, 21.6  $\mu\text{m}$ . Width, 2.8  $\mu\text{m}$ . Distinguished from other species of *Synedra* by its small size, linear shape, fine striae, and a central area that is small or absent.

Water-quality profile:

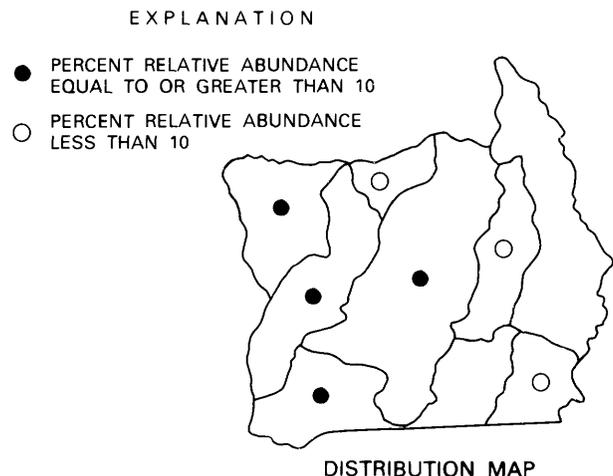
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ ) -----	115	438-11000	3090-5760	5760(30.9)
pH (units)-----	115	7.50- 8.80	7.88- 8.28	8.05(30.9)
Temperature ( $^{\circ}\text{C}$ ) -----	116	2.4- 30.2	13.3- 29.7	25.3(30.9)
Turbidity (NTU) -----	115	0.5- 60	0.9- 60	4.0(30.9)
Oxygen, dissolved (mg/L) -----	98	4.52- 15.3	7.02- 13.6	10.9(25.9)
Biochemical oxygen demand (mg/L)-----	36	0.8- 7.8	1.8- 2.6	2.2(25.9)
Hardness, total (mg/L $\text{CaCO}_3$ )-----	79	402- 3490	1020-2880	2880(30.9)
Calcium, dissolved (mg/L)-----	79	49.3- 360	124- 360	360(30.9)
Magnesium, dissolved (mg/L) -----	79	55.0- 645	143- 482	482(30.9)
Sodium, dissolved (mg/L)-----	86	66.1- 1950	410- 930	545(30.9)
Bicarbonate (mg/L) -----	86	260- 816	547- 764	572(30.9)
Carbonate (mg/L)-----	14	0.5- 38.4	14.0- 14.0	14.0(16.6)
Alkalinity, total (mg/L $\text{CaCO}_3$ )-----	86	213- 669	459- 627	469(30.9)
Sulfate, dissolved (mg/L)-----	86	134- 6900	1370-3530	3530(30.9)
Chloride, dissolved (mg/L)-----	86	0.4- 54.6	2.2- 24.0	19.2(30.9)
Fluoride, dissolved (mg/L)-----	85	0.1- 1.7	0.3- 0.6	0.5(30.9)
Dissolved solids, calculated (mg/L)-----	79	781-10400	2670-5500	5500(30.9)
Sediment, total suspended (mg/L)-----	103	0.2- 139	1.0- 64.2	5.2(30.9)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N) -----	48	0.01- 0.80	0.01- 0.03	0.03(25.9)
Nitrogen, total ammonia (mg/L as N)-----	70	0.01- 0.17	0.01- 0.02	0.01(25.9)
Phosphorus, total (mg/L as P) -----	76	0.010- 0.62	0.020- 0.25	0.020(25.9)
Phosphorus, total ortho (mg/L as P) -----	76	0.001- 0.52	0.003- 0.22	0.003(25.9)
Iron, total recoverable (mg/L) -----	54	0.02- 2.1	0.16- 0.79	0.18(30.9)
Manganese, total recoverable (mg/L) -----	45	0.005- 0.41	0.035- 0.18	0.035(25.9)

Ecological summary:

Prefers warm, brackish, extremely hard waters with large concentrations of sulfate; and small amounts of suspended sediment and turbidity. Apparently indifferent to substrate, stream size, and elevation. Tychoplanktonic? Spring and summer (May to August) dominant.

Distribution summary:

Widespread. Best population development in the western part of the study area.



ECOTYPE: *SYNEDRA FASCICULATA* (AG.) KUTZ.

Biotype(s):

*S. fasciculata* (Ag.) Kutz. var. *fasciculata*  
\**S. fasciculata* var. *truncata* (Grev.) Patr.

Reference:

Patrick and Reimer, 1966 (p. 142; pl. 5, fig. 16)

Herbarium slide number:

1-4-20

Mean percent relative abundance:

0.8

Percent occurrence:

42.2

Abundance-occurrence index:

34.3

Preferred percent occurrence:

1.4

Maximum percent relative abundance:

21.6

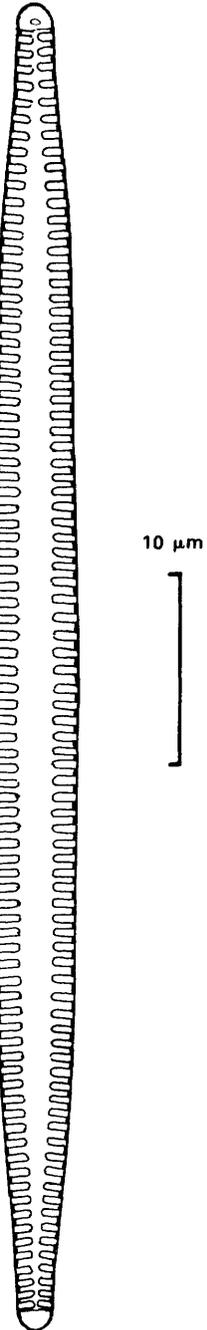
Station number: 3

Date: November 4, 1978

Type of collection: E

Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Length, 69.0  $\mu\text{m}$ . Width, 4.6  $\mu\text{m}$ . Distinguished from other species of *Synedra* by the clear ends, broad pseudoraphe, coarse striae, and a distinct jelly pore at one end of the valve. The two biotypes of this species are distinguished only by the shape of the pseudoraphe, the size of the valve, and the length-to-breadth ratio. Almost all our material from the southern Fort Union coal region fits the description for variety *truncata*.



Water-quality profile:

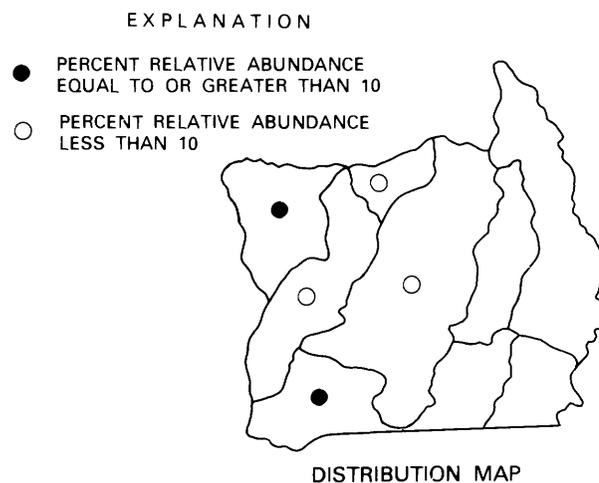
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	135	462-11000	1590- 5910	4200(21.6)
pH (units) -----	135	7.50- 8.70	7.82- 8.19	8.10(21.6)
Temperature ( $^{\circ}\text{C}$ ) -----	135	2.4- 30.2	6.2- 24.0	6.2(21.6)
Turbidity (NTU) -----	135	0.5- 60	0.8- 23	4.8(21.6)
Oxygen, dissolved (mg/L) -----	105	4.52- 19.0	6.20- 11.6	11.6(21.6)
Biochemical oxygen demand (mg/L) -----	43	0.8- 8.9	2.2- 3.2	2.5(21.6)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	78	237- 3490	1400- 2400	1400(21.6)
Calcium, dissolved (mg/L) -----	78	41.8- 360	187- 192	192(21.6)
Magnesium, dissolved (mg/L)-----	78	27.3- 645	224- 467	224(21.6)
Sodium, dissolved (mg/L) -----	85	18.3- 1950	537- 622	622(21.6)
Bicarbonate (mg/L)-----	86	226- 816	260- 576	576(21.6)
Carbonate (mg/L) -----	15	0.5- 36.0	-----	5.0(4.5)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	86	199- 669	213- 472	472(21.6)
Sulfate, dissolved (mg/L) -----	85	44- 6900	2200- 3150	2200(21.6)
Chloride, dissolved (mg/L) -----	85	0.4- 54.6	15.0- 45.6	15.0(21.6)
Fluoride, dissolved (mg/L) -----	84	0.04- 1.7	1.0- 1.0	1.0(21.6)
Dissolved solids, calculated (mg/L) -----	78	398-10400	3830- 4650	3830(21.6)
Sediment, total suspended (mg/L) -----	122	0.2- 135	0.7- 5.8	5.3(21.6)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	63	0.01- 0.71	0.06- 0.06	0.06(21.6)
Nitrogen, total ammonia (mg/L as N) -----	81	0.01- 0.57	0.01- 0.05	0.01(21.6)
Phosphorus, total (mg/L as P)-----	89	0.010- 0.62	0.020-0.040	0.020(21.6)
Phosphorus, total ortho (mg/L as P)-----	89	0.001- 0.52	0.002-0.008	0.002(21.6)
Iron, total recoverable (mg/L)-----	48	0.02- 2.1	0.21- 0.21	0.21(21.6)
Manganese, total recoverable (mg/L)-----	40	0.010- 0.41	0.064-0.064	0.064(21.6)

Ecological summary:

Prefers cool, brackish, extremely hard, sodium sulfate waters; gravel substrates (0.6- to 6-cm diameter); and small streams (0.1 to 10  $\text{ft}^3/\text{s}$ ) at middle elevations (2,500 to 4,000 ft). Sensitive to increased levels of suspended sediment and turbidity. Summer and fall (July to November) dominant.

Distribution summary:

Not found in the Powder River drainage. Best population development in Hanging Woman Creek and Armells Creek.



ECOTYPE: *SYNEDRA ULNA* (NITZ.) EHR.

Biotype(s):

- \**S. ulna* (Nitz.) Ehr. var. *ulna*
- S. ulna* var. *contracta* Ostr.
- S. ulna* var. *danica* (Kutz.) V. H.
- S. ulna* var. *ramesi* (Herib.) Hust.
- S. ulna* var. *spathulifera* (Grun.) V. H.
- S. ulna* var. *subaequalis* (Grun.) V. H.

Reference:

Patrick and Reimer, 1966 (p. 148; pl. 7, figs. 1-2)

Herbarium slide number:

1-5-1

Mean percent relative abundance:

0.8

Percent occurrence:

53.2

Abundance-occurrence index:

41.6

Preferred percent occurrence:

1.9

Maximum percent relative abundance:

35.6

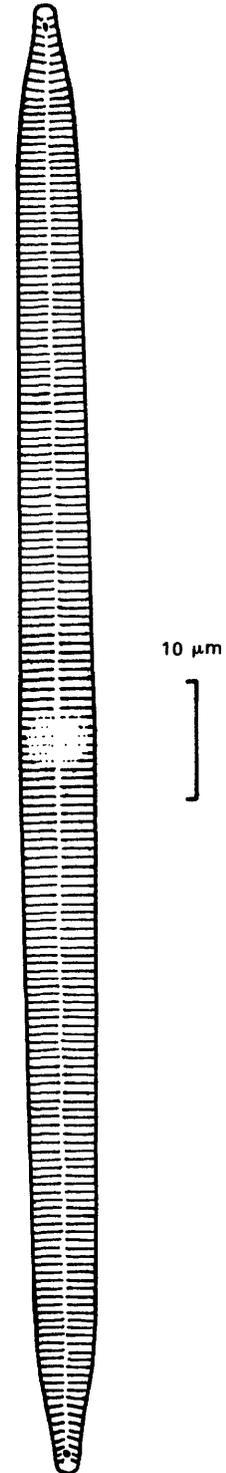
Station number: 48

Date: April 14, 1979

Type of collection: E

Description:

Striae, 12-14 in 10  $\mu\text{m}$ . Length, 122.0  $\mu\text{m}$ . Width, 6.3  $\mu\text{m}$ . A large, highly variable *Synedra*. Distinguished from other species of this genus by the shape of the ends and the shape of the central area.



Water-quality profile:

Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )-----	161	239-11000	1030- 1280	1280(13.4)
pH (units) -----	161	7.50- 8.80	8.20- 8.42	8.42(13.4)
Temperature ( $^{\circ}\text{C}$ ) -----	164	1.0- 30.5	5.0- 15.0	15.0(13.4)
Turbidity (NTU) -----	155	0.5- 1500	2.0- 6.7	6.7(13.4)
Oxygen, dissolved (mg/L) -----	123	4.52- 15.3	9.55- 13.8	9.55(13.4)
Biochemical oxygen demand (mg/L) -----	48	0.5- 7.8	-----	1.5(9.4)
Hardness, total (mg/L $\text{CaCO}_3$ ) -----	105	123- 3490	468- 468	468(11.9)
Calcium, dissolved (mg/L) -----	105	16.0- 328	83.2- 83.2	83.2(11.9)
Magnesium, dissolved (mg/L)-----	105	13.5- 645	63.0- 63.0	63.0(11.9)
Sodium, dissolved (mg/L) -----	114	9.1- 1950	64.0- 64.0	64.0(11.9)
Bicarbonate (mg/L)-----	120	15- 816	305- 305	305(11.9)
Carbonate (mg/L) -----	24	0.5- 38.4	-----	4.8(3.2)
Alkalinity, total (mg/L $\text{CaCO}_3$ ) -----	120	13- 669	250- 250	250(11.9)
Sulfate, dissolved (mg/L) -----	114	34- 6900	320- 320	320(11.9)
Chloride, dissolved (mg/L) -----	114	0.4- 174	5.2- 5.2	5.2(11.9)
Fluoride, dissolved (mg/L) -----	111	0.1- 1.7	0.3- 0.3	0.3(11.9)
Dissolved solids, calculated (mg/L) -----	105	184-10400	841- 841	841(11.9)
Sediment, total suspended (mg/L) -----	149	0.2- 893	4.2- 9.6	9.6(13.4)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)-----	85	0.01- 0.80	0.25- 0.25	0.25(11.9)
Nitrogen, total ammonia (mg/L as N) -----	94	0.01- 0.30	-----	0.01(9.4)
Phosphorus, total (mg/L as P)-----	116	0.010- 0.62	0.020-0.020	0.020(11.9)
Phosphorus, total ortho (mg/L as P)-----	119	0.001- 0.52	0.002-0.002	0.002(11.9)
Iron, total recoverable (mg/L)-----	76	0.02- 2.1	-----	0.21(9.4)
Manganese, total recoverable (mg/L)-----	65	0.005- 0.41	-----	0.065(9.4)

Ecological summary:

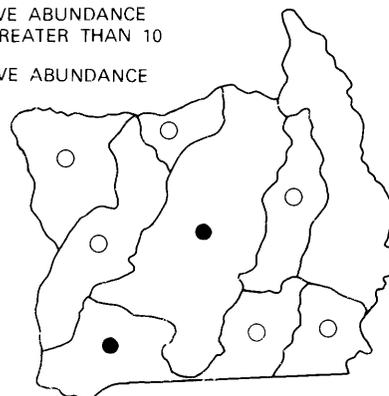
Prefers cool, fresh waters of large mineral content; relatively large concentrations of inorganic nitrogen; coarse gravel substrates or larger (greater than 3-cm diameter); and large streams (greater than 100  $\text{ft}^3/\text{s}$ ) at middle elevations (3,000 to 4,000 ft). Sensitive to suspended sediment and turbidity. Spring and fall (March to June and October) dominant.

Distribution summary:

Found throughout the study area except in the downstream part of the Powder River. Best population development is in the Tongue River.

EXPLANATION

- PERCENT RELATIVE ABUNDANCE EQUAL TO OR GREATER THAN 10
- PERCENT RELATIVE ABUNDANCE LESS THAN 10



DISTRIBUTION MAP

ECOTYPE: *THALASSIOSIRA PSEUDONANA* (HUST.) HASLE & HEIMDAL

Biotype(s):

*T. pseudonana* (Hust.) Hasle & Heimdal var.  
*pseudonana*

Reference:

Lowe and Busch, 1975 (p. 121; figs. 1-4)

Herbarium slide number:

1-1-17

Mean percent relative abundance:

0.5

Percent occurrence:

17.0

Abundance-occurrence index:

9.2

Preferred percent occurrence:

1.1

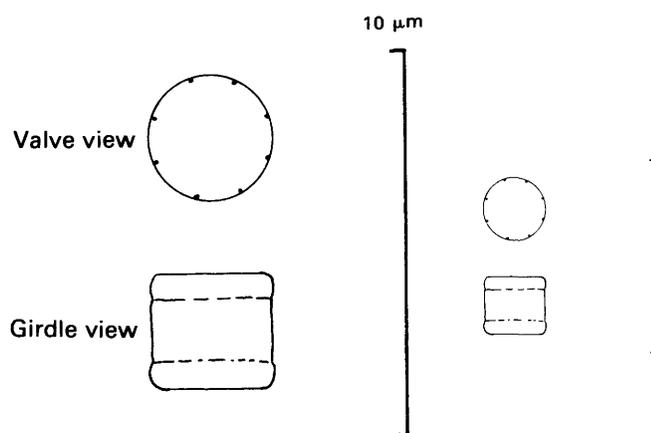
Maximum percent relative abundance:

31.4

Station number: 45

Date: June 21, 1978

Type of collection: E



Description:

Striae, (not visible under optical microscopes), about 50 in 10  $\mu\text{m}$ . Marginal fultoportulae (strutted processes), about 11 in 10  $\mu\text{m}$ . Diameter, 3.5  $\mu\text{m}$ . An extremely small centric diatom; very lightly silicified and barely visible, except under optimum conditions using the best quality optical microscopes. Distinguished from other centric diatoms by its very small size and the absence of visible ornamentation, except for the very faint marginal fultoportulae. In girdle view it tends to be relatively thick in relation to its width when compared to species of *Cyclotella* and *Stephanodiscus* (see drawing).

Water-quality profile:

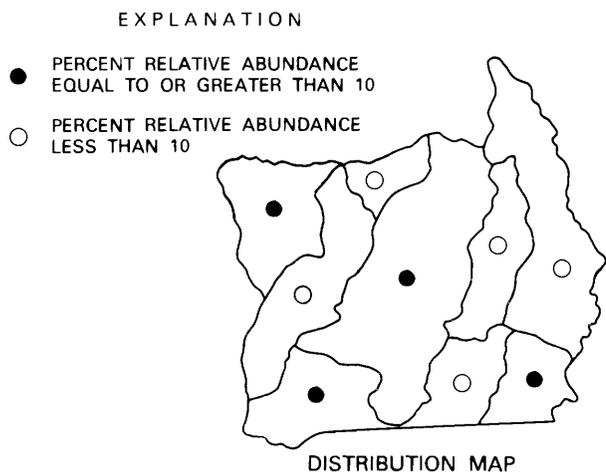
Variable	Number of samples	Range	Preferred range	Optimum (percent relative abundance in parentheses)
Specific conductance ( $\mu\text{mho/cm}$ )	55	478-11000	3090- 3310	3200(23.1)
pH (units)	55	7.60- 8.72	8.09- 8.29	8.09(23.1)
Temperature ( $^{\circ}\text{C}$ )	55	4.7- 24.0	12.4- 18.2	12.4(23.1)
Turbidity (NTU)	54	1.4-11600	4.5- 24	4.5(23.1)
Oxygen, dissolved (mg/L)	37	5.40- 15.3	9.10- 10.2	9.58(23.1)
Biochemical oxygen demand (mg/L)	15	0.5- 8.3	2.4- 2.6	2.4(22.5)
Hardness, total (mg/L $\text{CaCO}_3$ )	32	92- 3490	966- 1120	966(23.1)
Calcium, dissolved (mg/L)	32	28.8- 328	106- 124	122(23.1)
Magnesium, dissolved (mg/L)	32	5.0- 645	160- 208	160(23.1)
Sodium, dissolved (mg/L)	33	12.8- 1950	410- 440	433(23.1)
Bicarbonate (mg/L)	35	45- 755	528- 661	528(23.1)
Carbonate (mg/L)	4	1.0- 7.2		1.0(1.4)
Alkalinity, total (mg/L $\text{CaCO}_3$ )	35	39- 619	433- 542	433(23.1)
Sulfate, dissolved (mg/L)	33	70- 6900	1370- 1450	1430(23.1)
Chloride, dissolved (mg/L)	33	2.2- 174	10.4- 16.8	16.8(23.1)
Fluoride, dissolved (mg/L)	31	0.1- 1.5	0.3- 1.1	1.1(23.1)
Dissolved solids, calculated (mg/L)	32	448-10400	2670- 2880	2690(23.1)
Sediment, total suspended (mg/L)	48	2.9-22600	9.4- 64.2	9.4(23.1)
Nitrogen, total $\text{NO}_2 + \text{NO}_3$ (mg/L as N)	19	0.01- 0.32	0.01- 0.01	0.01(11.9)
Nitrogen, total ammonia (mg/L as N)	26	0.01- 0.11	0.02- 0.02	0.02(23.1)
Phosphorus, total (mg/L as P)	35	0.010- 0.62	0.020-0.060	0.020(23.1)
Phosphorus, total ortho (mg/L as P)	35	0.002- 0.52	0.007-0.021	0.007(23.1)
Iron, total recoverable (mg/L)	10	0.06- 2.1	0.79- 0.79	0.79(11.9)
Manganese, total recoverable (mg/L)	10	0.025- 0.37	0.18- 0.18	0.18(11.9)

Ecological summary:

Prefers cool, brackish, extremely hard, sodium sulfate waters; fine to medium gravels (0.2- to 3-cm diameter); and medium streams (1 to 100  $\text{ft}^3/\text{s}$ ) at middle elevations (2,500 to 3,000 ft). Tolerates some suspended sediment, turbidity, and chloride. Spring and summer (May to September) dominant.

Distribution summary:

Present in all hydrologic units of the study area. Best population development in the downstream reaches of Sarpy Creek, Hanging Woman Creek, Otter Creek, and the Little Powder River.



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